

UMTRA PROJECT

Uranium Mill Tailings Surface Project 1978 – 1998

Disposal Cell Design Summary Report



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Uranium Mill Tailings Remedial Action Project

Disposal Cell Design Summary Report



U.S. Department of Energy
Environmental Restoration Division
Albuquerque, NM

AUGUST 1999

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Introduction

The Uranium Mill Tailings Remedial Action (UMTRA) Project designed and constructed 18 disposal cells and one vicinity property cell using a “design based approach.” Under the Uranium Mill Tailings Radiation Control Act of 1978, 42 United States Code §7901 *et seq.*, the U.S. Environmental Protection Agency promulgated compliance standards for the disposal cells. Using the Environmental Protection Agency standards, the U.S. Department of Energy (DOE) developed the Project’s “design based standards” used for the design of each disposal cell.

This *Uranium Mill Tailings Remedial Action Project Disposal Cell Design Summary Report* is a companion document to the *UMTRA End-of-Project Report*, although both documents were written to function as “stand-alone” documents.

This report describes why the UMTRA cells were designed and constructed as they were. This report does not concentrate on what was done at each site during construction, or how many cubic yards of contaminated material was moved, because these UMTRA “statistics” are thoroughly covered by the *End-of-Project Report*. Without the institutional knowledge of why these cells were designed and built as they were, future generations of long-term surveillance and maintenance personnel may mistakenly judge that problems have developed. Understanding site-specific design issues and reasoning will help optimize long-term surveillance and maintenance efforts.

There isn’t a standard UMTRA Project disposal cell design. UMTRA disposal cells were designed specifically to perform properly, each on its individual site. The design goals in effect during the UMTRA Project’s 20-year life changed periodically to accommodate changes in the Environmental Protection Agency’s standards, as well as political, economic, environmental, and technical conditions. The UMTRA Project Team design and construction personnel’s experience increased with time. Past experiences, or lessons learned, caused significant changes in later UMTRA cell designs.

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Design Based Approach

Environmental Protection Agency Standards

The Uranium Mill Tailings Radiation Control Act of 1978, Section 108(a)(3), requires that the remedial action at the designated inactive uranium processing sites comply with standards established by the U.S. Environmental Protection Agency.

On January 5, 1983, the Environmental Protection Agency promulgated final standards in Title 40 of the Code of Federal Regulations Part 192, Subparts A through C. The standards became effective March 8, 1983. However, on September 3, 1985, the U.S. Court of Appeals for the Tenth Circuit remanded the ground water provisions of the regulations to the Environmental Protection Agency. On September 24, 1987, a proposed revision to the standards was issued by the Environmental Protection Agency (52 Federal Register 36000). The selection for the location of the proposed disposal sites and the design of the disposal cells followed these proposed standards until the final rule was published.

The design standards may be summarized as follows:

- The disposal site shall be designed to control the tailings and other residual radioactive material for 1,000 years to the extent reasonably achievable and, in any case, for at least 200 years.
- The disposal site design shall provide reasonable assurance that releases of radon-222 from residual radioactive materials to the atmosphere will not exceed 20 picocuries per square meter per second averaged over the entire surface of the disposal cell, or increase the annual average concentration of radon-222 in air at any location outside of the disposal site by more than 0.5 picocuries per liter.

On January 11, 1995, the Environmental Protection Agency published a final rule for ground water standards for remedial actions at inactive uranium processing sites. The standards consist of two parts: the first part governs the control of any future ground water contamination that may occur from tailings piles after remedial action, and the second part governs the cleanup of contamination ground water that occurred before the remedial action of the processing site.

Design Based Instead of Performance Based

UMTRA disposal cells were designed using a “design based standard” and not a “performance based standard”. Many former and current examples of design based standards may be seen in the building industry in the United States. For example, a steel-framed building is designed in the United States using the American Institute of Steel Construction (AISC) Specifications. All of the building’s beams and columns are sized and specified using equations and tables included in the current edition of the AISC Steel Manual. The building’s floors are designed for standard maximum office or storage area loading, the building code’s maximum design earthquake for the city and state where it is located. Steel members are manufactured and fabricated in conformance to other AISC Standards. After the building is fully designed and constructed in accordance to all applicable building codes and industry standards, the owners or tenants move in and conduct their business. No one performs a full-scale load test on the completed building to prove that it will perform properly. If the entire structure and all of its systems were designed and constructed in conformance with applicable codes and inspected during construction to prove conformance with the building codes, the job is completed when the building is finished.

Performance based standards on the other hand, involve final constructed performance of the product. For example, a race car may be specified to reach a top speed of 200 miles per hour (320 kilometers per hour) in 10 seconds or less. It has to accelerate in a controllable, safe manner, but the measure of its success is determined when a test-driver climbs into the cockpit and tests the vehicle. If it achieves the specified performance, it is approved, if it doesn't achieve specified performance it is not approved.

The DOE Albuquerque Operations Office, Environmental Restoration Division, and its contractors the Technical Assistance Contractor (Jacobs Engineering Group, Inc., Roy F. Weston, Inc., and AGRA Earth and Environmental) and the Remedial Action Contractor (MK Ferguson Company, and Morrison Knudsen Environmental) developed the UMTRA Project's design standard, published in the *Technical Approach Document*. This document was reviewed and concurred upon by the Project's regulator, the U.S. Nuclear Regulatory Commission. It was agreed that if UMTRA disposal cells were designed and constructed in accordance with methods and procedures included in the *Technical Approach Document*, and if inspection and testing during construction confirmed conformance with these "standards", then the cells would be accepted as complete and licensed by the Nuclear Regulatory Commission.

Disposal Cell Reports

For each of the 18 UMTRA disposal cells and the one vicinity property disposal cell, design and construction plans, and construction verification documents were produced. The three primary documents for each cell are the remedial action plan, the completion report and the long-term surveillance plan.

The remedial action plan contains the basis and approach for the remedial action, and it includes the design drawings and specifications for the remediation of the processing site and the construction of the disposal cell. The completion report documents the health physics monitoring for the removal of the contaminated residual radioactive

materials from the processing site and the placement of the contaminated materials in the embankment with its protective cover at the disposal site. The completion report also contains all of the design changes that were made during construction. The long-term surveillance plan documents the completed disposal site's surface features (i.e., location of fences, warning signs, markers, etc.) that may require periodic surveillance and maintenance from the Department of Energy during the life of the cell.

The Department of Energy, Nuclear Regulatory Commission and the appropriate state or tribal agency approves the remedial action plan. The completion report and the long-term surveillance plan are approved by the Department of Energy and the Nuclear Regulatory Commission.

A bibliography of these site documents is included at the end of this report.

Disposal Cell Design Principles

During the early years of the project, general UMTRA disposal cell design principles were developed by the Project team using available scientific, civil engineering, geotechnical engineering, and nuclear health physics principles. Cell designs were planned to contain solids, gases, and liquids. The major objectives of an UMTRA cell design, as stated in the Environmental Protection Agency regulations for the UMTRA Project (40CFR192), were to: provide stable long-term encapsulation of residual radioactive material including uranium mill tailings and contaminated mill facilities and equipment (solids); reduction of radon emanations (gases) to below regulatory levels; and protection of the ground water from pore water moving through the tailings (liquids).

When the term "long-term protection" is used with regard to a design basis, the term generally refers to a design standard based on extreme conditions required to satisfy the mandated 1000-year criteria. A few examples of such extreme design conditions include the Probable Maximum Precipitation (PMP) (which is precipitation from

a storm estimated to have the greatest probable rainfall intensity and amount for a given region) for erosion protection designs, the coldest winter projected to occur in the next 200 years for frost protection barrier design, and the maximum credible earthquake (MCE) for insuring the stability of the disposal cell's side slopes. The 1000-year design life criterion also prevented the use of any man-made materials in the cell designs except for temporary control, and it precluded the reliance on active control measures.

Solids Containment

Solids containment refers to the need to keep the contaminated materials in place by resisting erosion and other forces that could displace the materials. The standard for solids containment requires stability for 1000 years where reasonably achievable, and in any case for at least 200 years. To provide containment of the tailings' solids, consideration was given first to geologic site stability (surface water runoff erosion, river/stream flooding erosion, landsliding, and settlement). The disposal cell's surface layers and slopes were designed to resist wind and rain erosion, and ensure slope stability both during construction and in long-term service with earthquakes. The ground beneath a disposal cell was analyzed for foundation stability (i.e. bearing capacity) and settlement before construction. The cell was analyzed for settlement both during and after construction. Disposal cell covers were also designed to resist biointrusion by plants and animals, and to resist cover cracking due to desiccation, settlement stresses, and freeze-thaw cycles.

Control of Radon Gas

One of the major, early considerations of UMTRA cell designers was control of radon gas emanations. Regulations required that radon emissions from the contaminated materials be controlled to be less than 20 picocuries per square meter per second averaged over the entire surface of the disposal site. (An alternative standard allowed the possibility of using radon concentrations in air at the site boundary to show compliance, but this standard was

never applied due to the much greater difficulty in showing compliance via atmospheric modeling, compared with the surface emission rate standard.) It was decided to use a compacted clay layer, called the radon barrier, to control diffusion of radon gas to the atmosphere. This clay radon barrier was designed conservatively, assuming future drying of the layer to a minus 15 bar capillary moisture content. The radon barrier was designed to be protected from water and wind erosion by use of a rock "riprap" layer or a partially vegetated cover and at some sites it was protected from desiccation and freeze-thaw by a "freeze-thaw" barrier layer.

Control of Liquids

Control of liquids refers to reducing to acceptable levels the escape of potentially contaminated liquids containing contamination from the disposal cells. The primary focus was long-term ground water protection, although control during construction was also a design requirement. The initial standards for ground water protection were remanded by the courts during the early stages of the UMTRA project, which resulted in a change to more conservative disposal concepts at the sites that had not yet been constructed. Revised standards were proposed which were more stringent than the initial standards. These proposed standards were used as the design basis for the remainder of the project.

Several methods were used to control leachate contamination of ground water and surface water on the UMTRA Project. Water used during cell construction (for dust control and maintenance of optimum soil moisture content) was strictly controlled to avoid future build up of transient drainage water in the bottom of the cell. The term "transient drainage" was used to differentiate short-term seepage from disposal embankments from long-term seepage, which was expected to occur at smaller rates than short-term seepage. The low permeability clay cover layer (radon barrier) that was placed over the waste material to control radon emanation also controlled the seepage of precipitation water into the completed cell. Several innovative techniques were employed to remove water from

completed cells or control transient drainage formation during the early life of a disposal cell until long-term moisture equilibrium in the disposal cell was established.

Design Procedures

Consistent design procedures were developed by the UMTRA Project Technical Assistance Contractor and Remedial Action Contractor, and were concurred upon by the UMTRA regulators at the Nuclear Regulatory Commission. In 1989, a final project *Technical Approach Document* was prepared. Although the design procedures used were well defined and consistent, each UMTRA site was unique, resulting in a different cover and cell design at each disposal site. For each disposal cell the Remedial Action Contractor developed design basis memoranda for the design criteria and specific design approaches that would be used to achieve a design that would be in conformance with the *Technical Approach Document*. A summary of the UMTRA project cover designs is presented in Table 1. Typical cover layers most frequently used in UMTRA designs were provided for erosion resistance, frost penetration resistance, and radon/infiltration control. Special layers were provided as capillary breaks and biointrusion control. Figure 1 shows these layers in an illustrative cross section, highlighting many of the key components of UMTRA disposal cells.

Special Features of the UMTRA Embankment and Cover Design

Site-specific circumstances often required the use of special features that were not typically used. These circumstances included climate, technology development, and local stakeholders' concerns. Capillary breaks are a particular example of the evolution of cover layer designs for the UMTRA Project. At the time of the Canonsburg, Pennsylvania site design, capillary breaks were generally considered to be layers that were used to retard the upward movement of ground water into the disposal cell. The relatively close proximity of seasonal ground water at the Canonsburg site to the bottom of the disposal cell led to the construction of a capillary break below a clay liner placed at

the base of the disposal cell. As landfill technology progressed in the 1980s, capillary breaks found a new use in cover designs. The placement of a capillary break between an upper cover soil layer and a lower, less permeable layer could help improve cover performance. An important function of a near surface capillary break was to break the connection between the upper soil and lower cover layers; this can retard or stop matric suction in the lower layer from drawing seepage downward into the cell. On a slope, capillary breaks can reduce the area of breakthrough of seepage from the upper layer. Lastly, the capillary break impedes root penetration to a degree. Capillary breaks were constructed between the frost barrier layer and the radon/infiltration barrier at several later UMTRA Project sites.

Use of powdered bentonite clay amendment to reduce the permeability of radon barrier layers, use of vegetated covers versus rock covers, and prevention of biointrusion on the UMTRA Project progressed considerably from the beginning site (Canonsburg, Pennsylvania) to the last site (Maybell, Colorado). Examples of the evolution of UMTRA disposal cell design and reasons behind "why" changes were made are discussed for each disposal site in the following section of this report.

Placement of organic materials such as wood, paper, topsoil, or hydrocarbons in UMTRA disposal cells was strictly limited and controlled during construction. Placement of organic materials in relatively large concentrated "pockets" was prevented to avoid impacts of over cracking from excessive settlement of organic materials.

Synthetic liners, used to form an impermeable barrier beneath on-site retention ponds used during construction, were discarded in the disposal cells, because these liners were radiologically contaminated. The discarded synthetic liners were cut into strips and placed near the center of the disposal cells so as to not impact side slope stability or divert seepage out of the face of a slope.

A special feature that was not typically used was geosynthetic materials. The status of evidence during the project was not sufficient to show that synthetic materials would meet the standard for long-term performance. Synthetic materials were used in some cases, but were not required by design to maintain their properties for 200 to 1,000 years. Examples of geosynthetics used at disposal sites include the following:

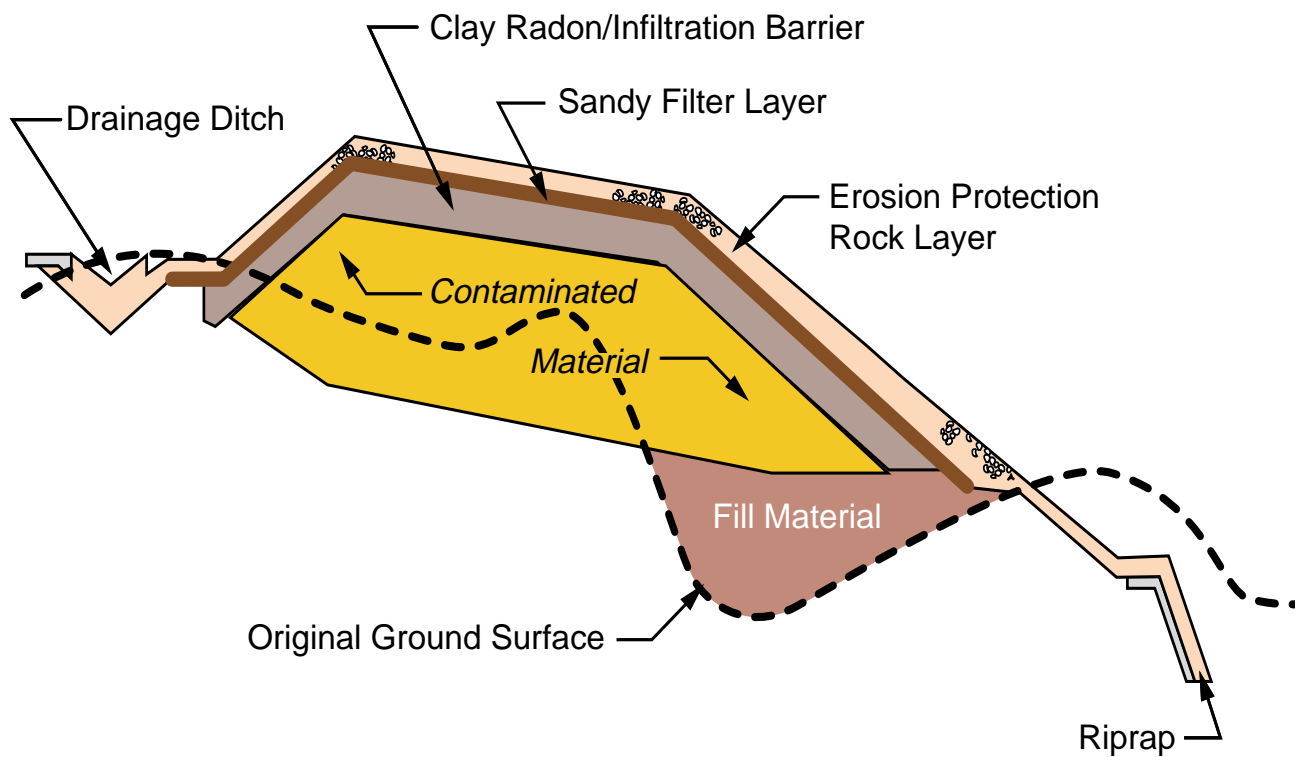
- Canonsburg – geotextile used to improve constructibility of the capillary break layer
- Durango – geotextile used in a geosynthetic clay liner to deploy a thin layer of bentonite
- Rifle – geomembrane placed in the bottom of the cell to collect and control transient drainage
- Falls City – geotextile used to improve constructibility of radon infiltration barrier over a small area of the embankment side slope where tailings slimes were exposed during construction.

TABLE I

UMTRA TITLE I CONSTRUCTED COVER DESIGNS

Site	Radon Barrier Material/Thickness (ft)	Freeze/Thaw Barrier, Material/ Thickness (ft)	Bedding Layer, Thickness (ft)	Erosion Protection, Rock or Vegetation (ft)	Special Layers, Capillary Break, Bio-intrusion, etc. (ft)
Ambrosia Lake, NM	Clay, 2.5'	Incorporated in Radon Barrier	0.5'	Riprap: Top, 0.5', Sides, 1.0'	None
Burrell, PA	Clay, 3.0'	None	1.0'	Rock, 1.0'	None
Canonsburg, PA	Layer A: Clay, 2.0' , Layer B: clay amended with bentonite, 1.0'	Incorporated in Radon Barrier	0.75'	Select Growth Media Soil, 1.0' over Riprap: Top, 1.0', Sides, 2.0'	None
Durango, CO	Top Slope: clay, 2.0', and geotextile bentonite layer Side Slope: clay, 2.0' , top 1.5' clay amended with bentonite	Sides: clay, 1.5' Top: clay, 2.5'	0.5'	Sides, Riprap, 1.0' Top, Vegetated	1.5' Capillary Break and Bio-intrusion Barrier Layer
Falls City, TX	Top: Clay, 3.0' Sides: Clay, 2.0'	0.5' Topsoil; 2.5' Silty Clay Growth Media	Top, None; Sides, 0.5'	Top Vegetated; Sides, Riprap, 1.3'	None
Grand Junction, CO	Clay, 2.0'*	Top: clay, 2.0'	0.5'	Riprap, 1.0'	None
Green River, UT	Clay, 3.0'	None	0.5'	Riprap, 1.0'	None
Gunnison, CO	Clay amended with bentonite, 1.5'*	Clay, 6.0'	0.5'	Riprap: Top, 0.5', Sides, 1.0'	0.5' Capillary Break
Lakeview, OR	Clay, 1.5'	None	0.5'	Top, Rock-Soil Matrix, 1.0'; Sides, Riprap, 1.0'	None
Lowman, ID	Clay, 1.5'	None	0.5'	Riprap, 1.0'	None
Maybell, CO	Sandy silt amended with bentonite, 1.5'	Sandy silt, 4.0'	0.5'	Riprap: 1' Top and Sides	None
Mexican Hat, UT/ Monument Valley, AZ	Clay amended with bentonite, 2.0'	None	0.5'	Riprap: Top, 0.67'; Sides, 1.0'	None
Naturita, CO	Clay, 3.0'	Clay, 5.5'	0.5'	Riprap, 1.0'	None
Rifle, CO	Clay, 1.5': the upper 1.0', clay amended bentonite, the lower 0.5' clay	Clay, 6.8' - 18.6'	0.5'	Riprap, 1.0'	Filter Layer between Radon Barrier & Frost Barrier, 0.5'
Shiprock, NM	Clay, 6.4' (top), 7.0' (sides)	None	0.5'	Riprap, 1.0'	None
Salt Lake City, UT	Clay, 7.0'	None	0.5'	Riprap, 1.5'	None
Slickrock, CO	Clay, 1.5'	Clay, 2.0'	0.5'	Riprap: Top, 0.67'; Sides, 1.0'	None
Spook, WY	Clay, 1.5'	N/A	N/A	N/A	10.0' High permeability layer
Tuba City, AZ	Silty clay, 3.5'	None	0.5'	Riprap: Top, 0.5'; Sides, 1.0'	None

* Clean fill dikes in place of radon barrier on side slopes.

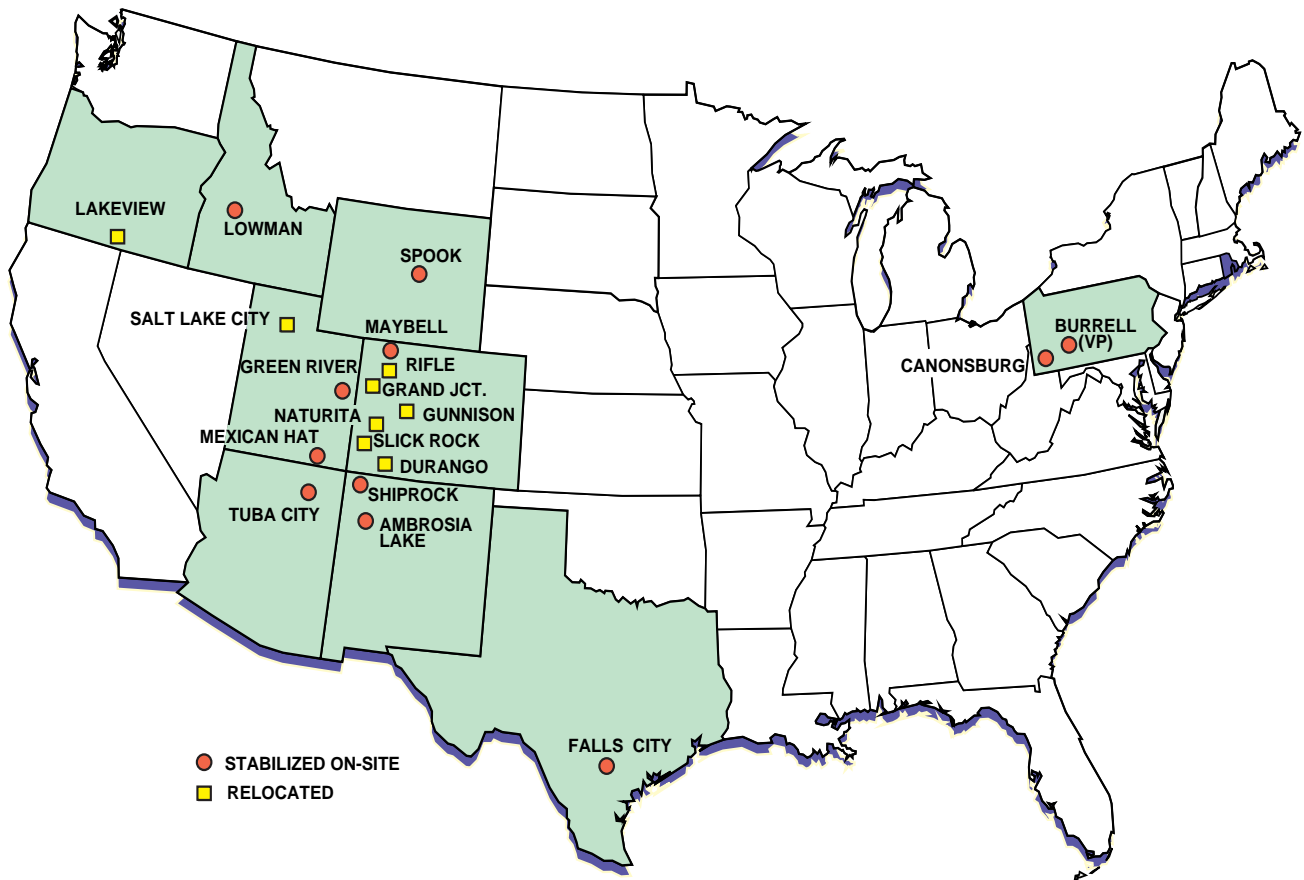


**Illustrative Cross-Section, Highlighting Many
of the Key Components of UMTRA Disposal Cells**

Figure 1

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CELL DESIGN INFORMATION



UMTRA Disposal Cell Locations

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Ambrosia Lake, New Mexico

Site Description

The former Ambrosia Lake mill and tailings site is located in McKinley County in northwest New Mexico approximately 85 miles (137 kilometers) northwest of Albuquerque. The residual radioactive material pile left after processing covered approximately 105 acres (42 hectares).

Cell Dimensions

The residual radioactive material was stabilized in place. The disposal cell is located on gently sloping land and is rectangular in shape. The cell rises some 50 feet (15 meters) above the surrounding terrain and is approximately 2,500 feet (760 meters) long by 1,600 feet (490 meters) wide. It is approximately 65 feet (20 meters) deep from its highest to its lowest point. The final disposal embankment covers 87 acres (35 hectares).

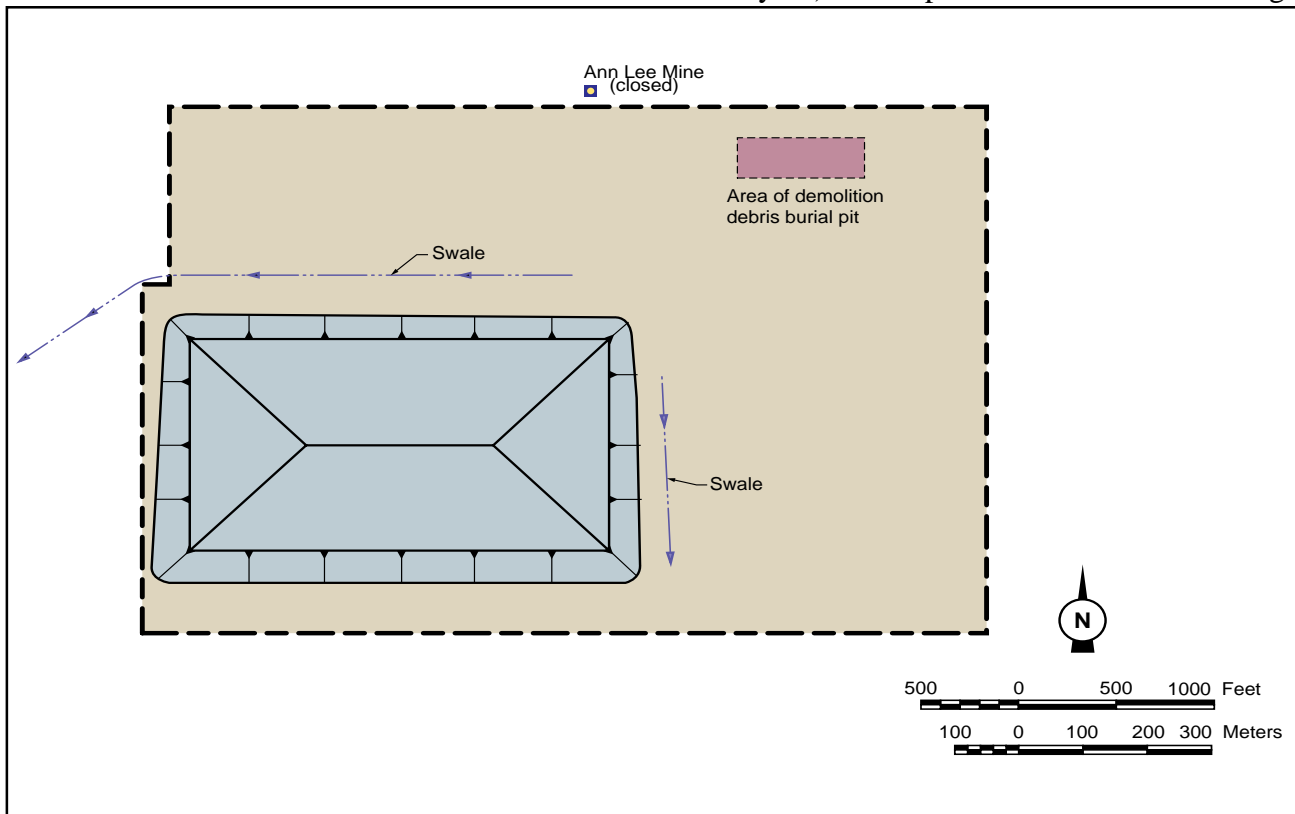
Site Specific Cell Design Features

Reduce Area of Cell

During the early stages of design for the Ambrosia Lake cell there were concerns about reducing the area of the cell by relocating a portion of the tailings on top of the existing pile. The weight of relocated tailings and of wind-blow materials placed on top of wet tailings materials located in the existing pile could cause settlement problems. But there was a strong economic incentive to build up the Ambrosia Lake cell and reduce the area of its “foot print”.

As the UMTRA Project progressed, it became apparent that cover costs could be a significant part of the total remedial construction cost. Materials for covers tended to cost more than earlier expected due to the following factors:

- High quality rock required for erosion protection riprap and graded filters (i.e. bedding layers) on disposal cells and in drainage



ditches often was not readily available.

- Low permeability soils needed to construct radon barriers often did not occur in relatively uniform deposits thus requiring selective excavation.
- Construction and quality control efforts were required to meet stringent standards set by Environmental Protection Agency and others.

It became apparent to project designers that a cost trade-off existed between the cost to cover *in situ* tailings and the cost to consolidate the tailings into a smaller area to reduce the disposal cell cover costs. A cost trade-off analysis was made for the Ambrosia Lake embankment. The Ambrosia Lake tailings pile had areas of tailings that were relatively thin. The cost of relocating subpile materials contaminated by the overlying tailings was also considered. Additionally extensive settlement analyses and field settlement load tests were required to verify that excessive settlement and associated cover cracking would not occur. Using this approach, the size of the final embankment was optimized.

Test Embankments for Settlement Measurements

Ambrosia Lake was the first UMTRA Project site where the issue of post-construction settlement became a major issue. Previously, a small part of the Shiprock embankment was scheduled for construction and settlement was monitored to check if consolidation settlements occurred rapidly following placement of overlying fill. However, this approach was not viable at the Ambrosia Lake site because the size of the embankment that would be affected by post-construction consolidation settlement was too large. Using reasonably conservative assumptions and laboratory test data, estimates of post-construction settlement based on consolidation calculations for the Ambrosia Lake embankment were large enough that cracking of the radon/infiltration barrier was predicted. Various solutions were considered, including prefabricated

drains to dissipate consolidation-induced pore water pressures and staged construction that allowed most settlement to occur before the radon barrier was constructed. However, the options considered were either too costly or not practicable from a scheduling viewpoint.

Knowledge of the layering of tailings deposits and their behavior (i.e. coarser grained material interlayered with finer grained material which allows significant horizontal drainage of consolidating layers) indicated the likelihood that full-scale settlements would occur much faster than estimated by the conventional consolidation-theory calculations. The key issue was the use of laboratory test data from small samples and the assumptions of drainage conditions in the analysis. Furthermore, there were no practical means of obtaining sufficient data to modify the properties and drainage conditions for the full-scale facility.

A decision was made to construct and monitor two test embankments to either justify a large cost and schedule savings by allowing single-stage construction, or at worst, to show that a more costly approach was required. The two test embankments were constructed and numerous measurements were made to record settlements, pore water pressures, and total stresses. The embankments were large enough to simulate full-scale construction 20 feet (6 meters) high and 200 feet (60 meters) square at the base. A reanalysis was made to adjust earlier calculations to fit the observed field measurements.

The reanalysis confirmed that most embankment consolidation settlement occurred rapidly after placement of the fill. The part of the consolidation settlement that would affect the cover layers could be estimated more accurately and showed that cracking of the radon/infiltration barrier was unlikely to occur. A decision was made to proceed with single-stage construction. As additional confirmation, settlement measurements were made during the full-scale construction. The measurements during construction confirmed the predicted cover settlement.

Construction of two test embankments enabled the cost and schedule for the Ambrosia Lake embankment to be dramatically reduced. The experience at Ambrosia Lake also facilitated design and construction at other sites such as Falls City, Texas; Mexican Hat, Utah; and Maybell, Colorado. At those sites, it was only necessary to monitor settlement during construction. Thus, the UMTRA Project realized substantial savings from the Ambrosia Lake experience.

Use of Swales Rather Than Riprap-Lined Ditches

The size of the Ambrosia Lake embankment and the drainage area up-slope from the embankment created the potential for large flood flows at the toe of the embankment under probable maximum precipitation (PMP) rainfall events. The use of riprap-lined ditches for diversion of flows around the embankment would have resulted in high costs for construction. Since the Ambrosia Lake site was relatively flat, and the area was large, a decision was made to use broad swales instead of narrow ditches. Use of swales reduced cost and allowed for greater flexibility, which became critical due to unexpected conditions. Practically speaking, the most critical ditch section often controls the entire riprap gradation design. Revisions to riprap gradations during construction can be costly and impractical, especially when the required rock sizes are not locally available. Unlike a site using riprap rock-lined ditches, when unexpected additional excavation for contaminated materials was required at the Ambrosia Lake site, the swale grades and elevations were easily adjusted to minimize additional earthwork while meeting the hydraulic design criteria for the swales. The fact that only earthwork changes were required, made the design revisions faster and easier compared with the revision process and results that were likely if riprap-lined ditches had been used.

Hydraulic design of the swales included the following key elements:

- Non-erodible velocities for the soils and sparse vegetation at the site.

- Large swale cross-sections that could be partially filled with sediment over time without causing flows to impinge on the embankment.
- A check to confirm that riprap on the embankment side slopes would be stable in the event that sediment accumulations in the swales over time caused flows to impinge on the embankment.

High Quality Riprap Used at Ambrosia Lake

The use of high quality basalt rock for riprap helped reduce the required rock quantities. In addition, the dry climate at the site and gentle grades suggested that a one-foot-thick (0.3 meter) riprap layer was not needed on the top slope of the embankment. Required particle sizes were also small enough to fit within a layer thinner than one foot (0.3 meter). Project experience with placing and “track-walk” compacting the rock to a tight, rather smooth surface, indicated that riprap layers could be placed within relative small tolerances. This combination of factors led to a decision to use a 6-inch (15 centimeters) thick rock layer on the top slope of the embankment.

Debris Disposal

The Ambrosia Lake site contained many former mill and operations buildings. Since most of these buildings were contaminated, disposal in a controlled area was required. The most contaminated debris was placed in the tailings embankment while slightly contaminated or uncontaminated debris was disposed of in a separate disposal pit located northeast of the tailings embankment. Long-term settlement in the debris pit was not considered as critical as settlement that might occur in the tailings embankment. Thus, allowing debris to be placed in a separate pit reduced debris placement costs and expedited placement by allowing the subcontractor to reduce cutting of debris, a laborious process.

Debris placement in the tailings embankment was performed as follows:

-
- Voids in the debris pile caused by nesting or other means were avoided.
 - Debris was placed in an area of soft tailings in a former pond area on the pile. The debris was placed to bridge over soft wet areas and facilitated placement of overlying fill by providing a firm base where none had existed.
 - Fill placed above a specified elevation had to meet minimum compaction densities. Fill placed below that elevation was rolled but not tested for compaction, since the fill was not judged to be less stable or more compressible than the soft tailings subgrade in that area.
 - Debris and fill were placed in a manner that did not create mud waves in wet tailings slimes ahead of placement areas.

This approach to debris disposal was facilitated by the disposal cell settlement assessment that demonstrated that the soft tailings in the embankment could be stabilized in place. Substantial quantities of debris were placed in a cost-effective manner using this approach.

Disposal Cell Special Features

Along the northern end of the site in a fenced area there is a partially filled mine vent-shaft called the Ann Lee mineshaft. Fill placed in, and over, this shaft have settled in the past, and could settle again in the future. Surface contamination in the area was not remediated based on safety concerns regarding subsidence potential. If future settlement is observed or contamination detected in the immediate vicinity of the shaft, it has no relation to performance of the debris disposal pit located in the northeast corner of the site, or of the disposal cell.

Burrell, Pennsylvania

Site Description

The Burrell disposal site is officially called Vicinity Property CA-200 and is located in Burrell Township, about one mile (1.6 kilometers) east of the city of Blairsville, Pennsylvania. The vicinity property contained approximately 9 acres (3.6 hectares) of contaminated surface area.

Cell Dimensions

The residual radioactive material was stabilized in place. The Burrell disposal cell is roughly oblong in shape. It stands 20 feet (6 meters) above the surrounding terrain and varies in depth from 3 to 25 feet (1 to 7.6 meters).

Site Specific Cell Design Features

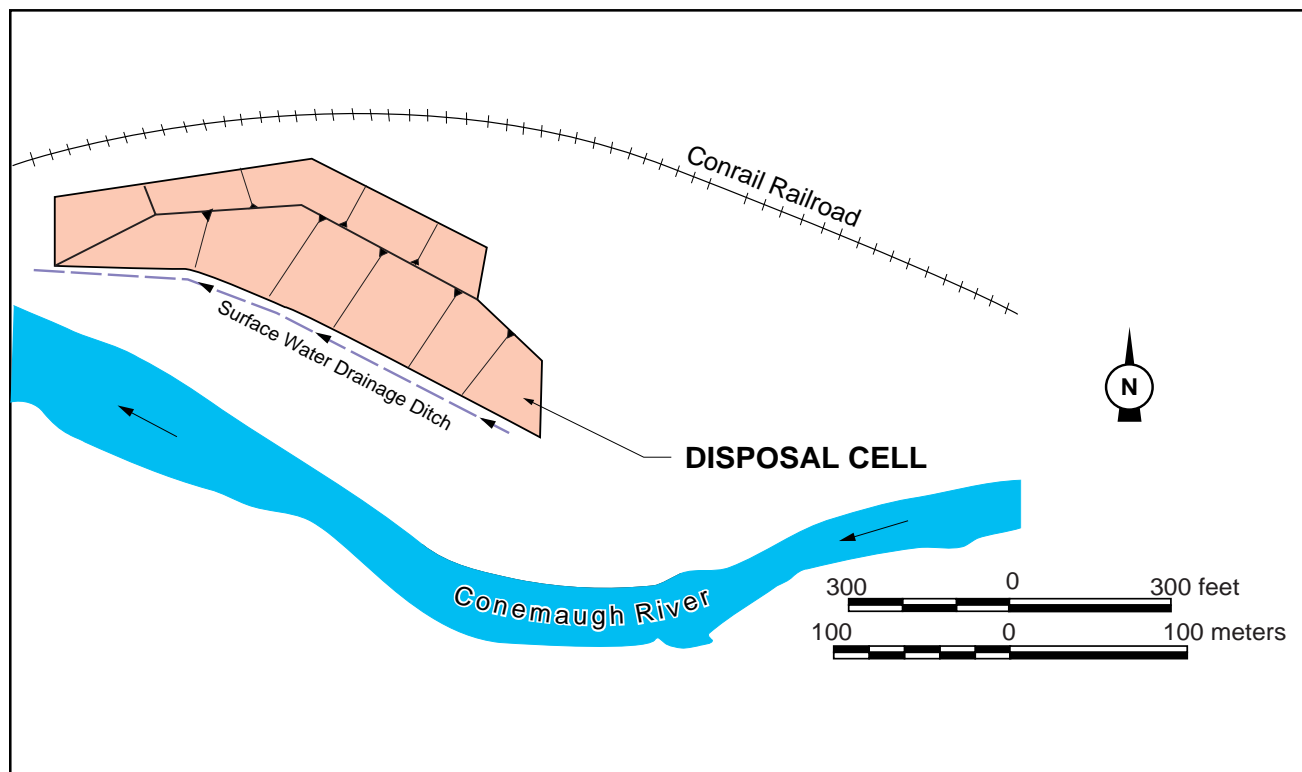
Vicinity Property Cell

Since the Burrell disposal site is a “vicinity property” and not a designated UMTRA processing site, there are differences in the design criteria applied to the site and in the procedures used by regulators

to evaluate the design and construction of the Burrell disposal cell. In general, the design and evaluation criteria applied to this cell were less stringent than those applied to designated processing site disposal cells.

The site’s remedial action plan is contained in the remedial action agreement between Conrail Railroad, the Commonwealth of Pennsylvania, and the Department of Energy.

The Burrell disposal cell was constructed on top of a preexisting railroad landfill, which included railroad ties and debris in the bottom of the fill. Theoretically, waste not associated with the UMTRA project could exist at the bottom of the Burrell disposal cell. As mentioned above, unlike the UMTRA processing site disposal cells, the Burrell disposal cell was not specifically designed for resistance of biointrusion, and was not designed with a freeze-thaw protective layer. This cell was designed with a riprap rock cover in a heavily vegetated, forested area where a deep vegetated cover might have otherwise been considered.



Surface Water Drainage

The cell was designed to allow for surface water drainage to pass through a portion of the cell's rock layer. This rusty looking surface water drainage originates on the up gradient side of the cell and due to the surrounding terrain and the location of the railroad tracks naturally flowed through the original Burrell landfill. The drainage gives the appearance of seepage on the downhill side of the cell that could easily be misinterpreted as leachate seepage from the disposal cell. On several occasions, field personnel from the UMTRA Technical Assistance Contractor and the Remedial Action Contractor have sampled this drainage water to check for radionuclides, and none have been detected.

Canonsburg, Pennsylvania

Site Description

The 30 acre (12.1 hectares) Canonsburg site lies between Chartiers Creek and the Conrail tracks in the Borough of Canonsburg. The main cleanup site, which originally included the processing buildings, is located west of Strabane Avenue in a fenced area. The controlled, fenced area contains the Canonsburg site disposal cell. In an uncontrolled area located east of Strabane Avenue there is a grassy field that was originally a sludge disposal area that was only a few feet (less than a meter) above Chartiers Creek's streambed elevation. This area, referred to as Area C in the site documentation, was cleaned and filled to raise the ground above seasonal flood levels.

Cell Dimensions

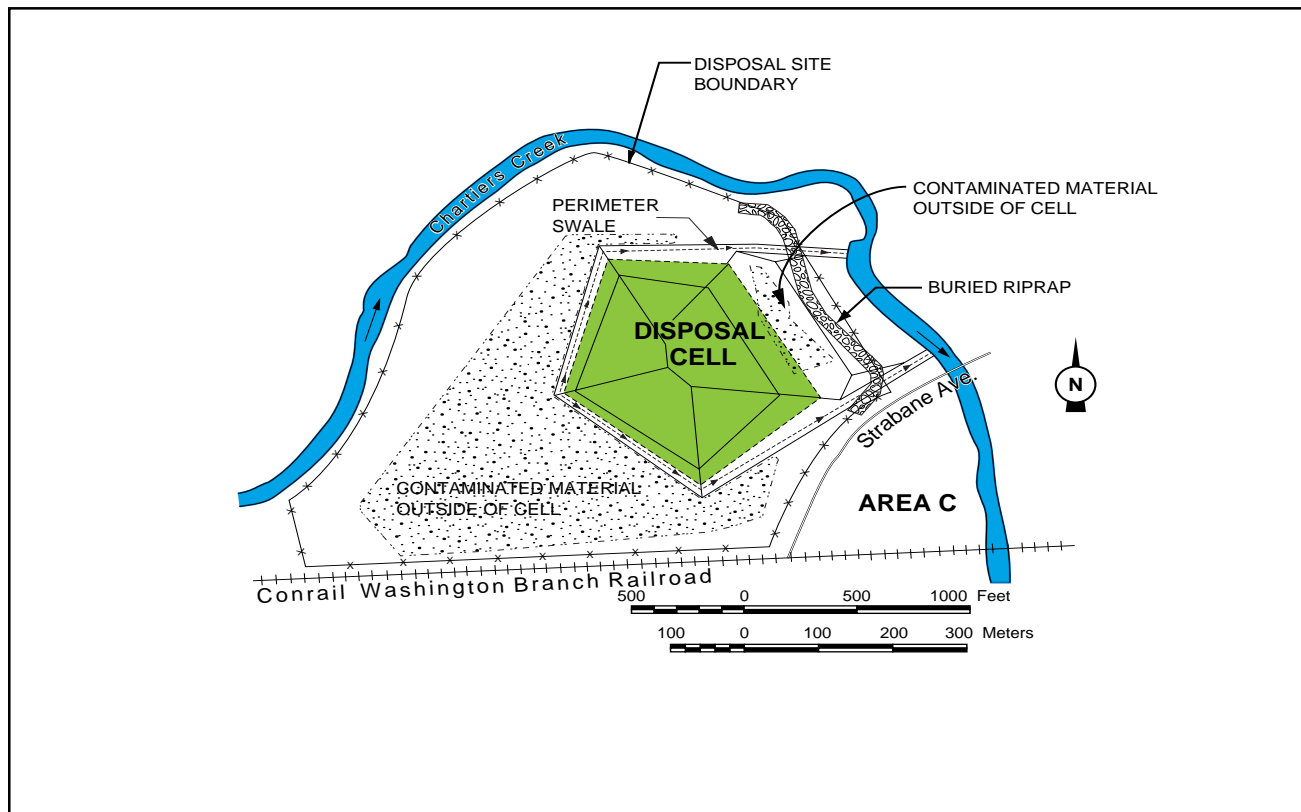
The residual radioactive material was stabilized on site. The Canonsburg disposal cell is roughly pentagonal in shape and is approximately 800 feet (245 meters) long by 760 feet (240 meters) wide.

Site Specific Cell Design Features

First UMTRA Cell

The Canonsburg site was the first UMTRA site remediated. In the early years of UMTRA, it was the project plan to remediate most, if not all of the sites, "in place" or "on site".

Although the Canonsburg site appears to have a vegetated cover for erosion protection, such is not the case. Erosion protection on the Canonsburg disposal cell consists of riprap as the fundamental element for preventing erosion. Community preferences and aesthetics were significant drivers for using a vegetated layer over the rock layer that covers the entire cell. In 1983, community input and economics guided the UMTRA team to keep the cell adjacent to Chartiers Creek. The possibility for intense storms that could affect the creek made it impracticable to design a vegetated cover that would have adequate erosion resistance for



long-term performance. Therefore, the riprap cover was designed for the most severe condition that could occur with an erodible, vegetated soil layer placed over the riprap. The most severe condition selected for the design was the formation of a gully that would erode completely through the soil layer, causing the flow in the gully to impinge on the riprap.

The design accounted for two key factors. The first was an estimate of the area on the cell slopes that would contribute runoff into a gully. The drainage area was taken to be a function of degree of slope and slope length. The second factor was the assumed gully cross section that would contain the flow. Standard riprap sizing methods were used to complete the design. This approach provided a means of resisting the probable maximum precipitation (PMP) event's erosion even if the soil cover erodes in a way that causes the largest flow forces to impinge on the riprap.

Buried Riprap Wall and Blind Ditch Outlets

The potential for stream bank erosion from Chartiers Creek was a key design issue for the disposal cell. The floodplain in Chartiers Creek extended up to the cell slopes along the north side of the cell, and bank erosion during an extreme flood was a possibility considered in design. A special study was conducted to help understand the process of the creek morphology and to determine the effects of floodplain management plans by the U.S. Army Corps of Engineers on the cell design. A decision was made that the cell required protection from undercutting caused by either progressive or catastrophic erosion of the stream bank. However, stabilization of the existing stream bank was not considered the best approach. Ongoing creek morphology processes, erosion due to floods, and permit issues dictated a different approach.

The design approach used was a buried riprap wall placed adjacent to the cell. The design location avoided constricting the creek flow during a flood that eroded the existing bank, and allowed the wall to be connected to the riprap on the cell's side slope. An excavation was made to place the toe of the

sloping wall below the anticipated scour depth for the design flood, and key the bottom of the riprap wall into bedrock. Existing bedrock elevations were considered adequate to protect the upstream end of the wall from erosion, and the wall was wrapped around the downstream edge of the cell to prevent erosion of the cell by eddy flows.

A similar solution was applied to the ditch outlets for the ditches placed at the toe of the cell side slopes. If the ditch outlets were constructed through the existing creek banks, the outlets would likely be damaged by erosion on the upstream and downstream edges of the outlets. Other considerations similar to those that determined the approach for the buried riprap wall applied to the ditch outlets as well. Consequently, the buried riprap wall was also designed for protection against ditch outlet flows, which assumed that the soils on the creek bank had been eroded. Thus, erosion of the existing creek banks at the ditch outlets was considered an expected result of the design approach, and does not require maintenance or repair.

Low Permeability Cover Layers

Two low permeability cover layers were constructed on the cell. The upper layer was the primary infiltration barrier and part of the radon barrier. The upper layer was one foot thick (0.3 meters), amended with 10 percent bentonite by weight, and had a maximum allowable design permeability of 1×10^{-7} centimeters per second. The lower layer was primarily for radon attenuation, and was two feet (0.6 meters) thick with a maximum allowable permeability of 1×10^{-6} centimeters per second. The practice for low permeability soil covers on waste disposal facilities was not well-developed in the early 1980's, so the design drew upon available information that included low-permeability liners for impoundments, canals, and other applications. The use of *in situ* permeability testing was likewise not very advanced and incorporated in common practice at the time. Therefore, laboratory testing was used as the basis for acceptance of the cover layer permeabilities.

Test fills were constructed to confirm the design requirements for both layers. The importance of kneading compaction, compaction moisture contents at or above optimum moisture content, and moldable soil without large dry clods was considered. Construction procedures and quality control were implemented that addressed these factors. Bentonite was spread manually according to a calculated grid on loose lifts of soil and then mixed prior to compaction. The tests for permeability were made on undisturbed samples extracted from each test fill and tested in the laboratory. A simplified specification of minimum moisture content relative to optimum and a minimum relative compaction percentage was used for cell cover construction. Procedures developed for a larger zone of acceptable moisture-density combinations were not yet available for use in constructing the Canonsburg cell in 1984-1985.

This first UMTRA site incorporated laboratory testing and test fills for permeability as the basis for confirming the design permeability. It is important to note that strict quality control and detailed specifications were used to help reduce the potential for large-scale effects to cause full-scale layer permeabilities to be greater than laboratory-derived permeabilities.

Rock Quality

Historic use of rock in construction helped demonstrate that the rock could be durable for the design life of a disposal cell. Observations were made of quarry rock that was used in exposed portions of building foundations and cobblestone streets for 80-90 years without substantial weathering. This evidence was weighed together with laboratory tests and petrographic examination to determine that the rock quality was acceptable.

Contamination Remaining Outside the Disposal Cell

During construction, just north of the disposal cell, called Area B, residual radioactive material was encountered beneath the wastewater retention basin. It was not possible to excavate this material

and place it in the disposal cell, because the required excavation would have undermined the north excavation sidewall of the disposal cell or it would have required removal of the sedimentation/retention basin (which would have been a violation of the National Pollution Discharge Elimination System permit). This contaminated material was left between the cell and the buried riprap wall, so it is protected from Chartiers Creek erosion, but does not have a radon barrier cover layer.

Along the southern and western sides of the disposal cell, outside the cell and inside the fence, vicinity property material having less than 100 picocuries per gram were placed. This vicinity property material was transported from a local property that was remediated after the residual radioactive material in the disposal cell was covered with radon barrier material. The decision was made to spread and bury the material outside the cell because the radioactivity of the material was low and there were no other practical disposal options available.

A written summary was prepared to show the locations of the materials, the estimated radon release rates, and long term erosion expected in those locations. Unlike the material left in Area B, the vicinity property materials left outside the southern and western sides of the cell were covered by two to three feet of compacted topsoil and were not protected by a cover designed for the probably maximum precipitation. It was determined that this buried vicinity property material was located above the high water level from a 100 year flood event on Chartiers Creek. Erosion in these locations are to be monitored by the Long-Term Surveillance Program and grades restored if excessive erosion occurs.

Area C Thorium Cleanup

Cleanup criteria for Thorium were not yet fully developed in the 1983 through 1985 time period. The cleanup criteria for Thorium-230 were based on the average Thorium-230/Radium-226 ratios for several large areas. A grid-by-grid confirmation

approach for Thorium-230 was not used until later in the project. Prior to licensing of the Canonsburg site, three problem areas for Thorium-230 were discovered in the records of Area C, and were addressed by site specific analyses that were reviewed by and concurred upon by the Nuclear Regulatory Commission.

Required Maintenance

Periodic mowing of grass on the cell cover is performed by the Long-Term Surveillance Program to avoid in-growth of large, deep-rooted plants such as trees and shrubs.

The perimeter fence is required to maintain a “controlled area” for this site. Trees and shrubs that drop limbs or grow through or over the fence will be trimmed and maintained, and damage to the fence that allows unauthorized access to the site will be repaired.

Trees and shrubs will grow in between the riprap located in the drainage ditches. Even though this is not problem for the buried residual radioactive material, this vegetation is periodically removed so as to not clog the drainage ditches.

Durango, Colorado

Site Description

The Durango disposal site is located in Bodo Canyon just outside the city limits of the city of Durango in southwest Colorado. The Bodo Canyon disposal site comprises 120.6 acres (48.8 hectares).

Cell Dimensions

The processing site residual radioactive material was relocated to the Bodo Canyon site. The disposal cell is roughly rectangular in shape, and is 2,200 feet (670 meters) long by 1,100 feet (335 meter) wide. It is constructed partially below grade and is approximately 90 feet (27 meters) from its highest to its lowest point.

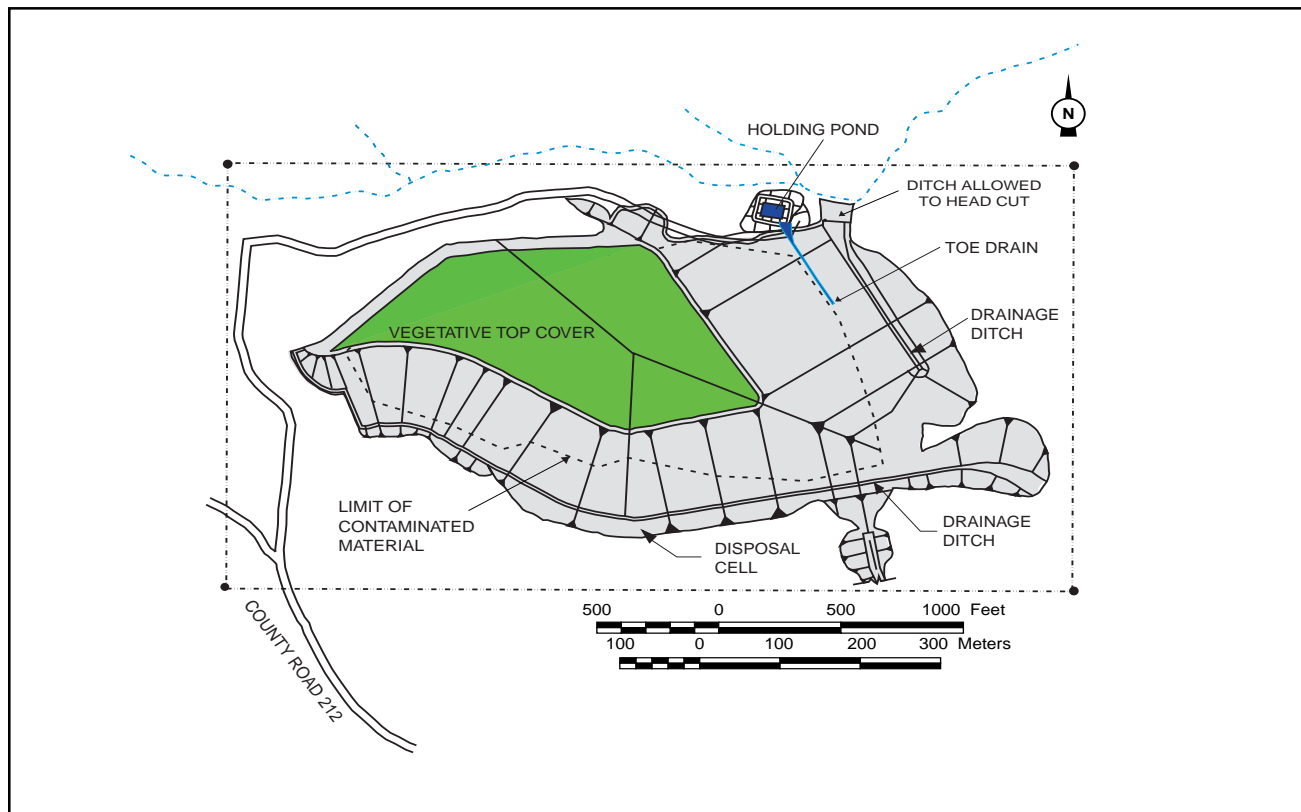
Site Specific Cell Design Features

Cover Design

Revised ground water protection requirements, technology development, and State of Colorado

preferences dictated a major change in the approach to cover design for the Durango disposal cell. Design criteria for the cell required a very low rate of infiltration into the cell from the cover, based on ground water protection goals. Technology development for landfill covers was progressing, and the State of Colorado lobbied to incorporate several promising features into the cover design. These features included the following:

- A vegetated cover to reduce infiltration by storing water from high infiltration periods and then using vegetation to transpire the water from the rooting zone.
- A geosynthetic clay liner (bentonite mat) to provide a very low permeability layer beneath the vegetated cover.
- A biointrusion layer to help restrict the penetration of roots below the rooting medium layer, and to help reduce the downward flow of water by capillary action from the bento-



nite acting on the rooting medium soil.

Low Permeability Barriers

The draft Environmental Protection Agency ground water regulations for the UMTRA project were released just prior to final design and construction of the Durango disposal cell. The ground water protection strategy for the Durango disposal cell resulting from these new draft ground water regulations drove the need for an extremely tight (i.e. low permeability) cover. The clay barrier in the bottom of the cell was also installed as part of that effort. The geotextile bentonite clay liner material that was used in the cover design reflects this need for an extremely low permeability cover (1×10^{-8} centimeters per second). The geotextile clay liner was needed to make sure the cover had a lower permeability than the resulting permeability of the liner at the base of the cell. Bentonite amendment of on-site soils was used in the cover on the sideslopes of the cell, because there were concerns that the geotextile clay liner would cause slope stability problems. This low permeability cover system was completed before it was realized that the alluvium in the foundation of the disposal cell would de-saturate with time.

Vegetative Cover

The Durango cell was a departure from previous arid region covers in that a vegetated cover was used on the top. Previously it was felt that vegetation could not be sustained during dry years in arid climates. The site specific climate coupled with the use of native plants showed that a vegetated cover would work for the Bodo Canyon site. The goal of the surface vegetation was to establish a plant community on the topslope that would be self sustaining and tolerant of the full range of climatic conditions. A vigorous plant community will transpire most of the moisture that enters the soil and will resist erosion of the underlying material. The distribution of the soil used as the rooting medium consisted of clay loam on top of the cobble/choked rock layer and a loam/silt loam placed over the clay loam. A seedbed was prepared that would favor germination and early growth, as well as re-

sist erosion until the vegetation became established. Computer models were used to demonstrate the improvement in cover infiltration due to evapotranspiration.

The Durango cell was specifically designed with a layer to resist plant and animal biointrusion. Large rocks in this biointrusion layer were designed to be equal to one-third of the mass of the largest burrowing animal known to be present in the area. The thickness of the barrier was based on three diameters of rock on the theory that plant roots would not extend through dry (non-capillary) spaces.

Drainage Ditch Allowed to Headcut

The ditch along the northeast side of the cell was designed to allow limited headcutting from erosion forces. A large quantity of riprap was placed in the ditch so that if headcutting occurred, the riprap would armor the eroded face. A buried (not visible on the surface) cutoff wall of erosion resistant rock was installed upgradient from the ditch outfall to prevent erosion migration to the base of the disposal cell.

Toe Drain

A toe trench drain along the eastern end of the site is the most unique feature of the Durango cell. The original design of the Durango cell intended for seepage of transient drainage water from tailings inside the cell to seep out the bottom of the cell into a deep unsaturated zone of soil and relatively impermeable bedrock. During the second year of construction, seepage was observed coming from the lower portion of the eastern embankment slope. This seepage was later identified to be transient drainage collecting on a winter cover clay layer that was inadvertently left in place at the start of the second construction year. The toe trench drain was installed to remove transient drainage water that collected on the winter cover layer and remove it from inside the cell before it could seep out the side slope of the embankment. Long term drainage of transient water out the toe drain and into a lined retention pond lowered water in the cell to a

safe level that prevents seepage from the base of the eastern embankment slope of the cell. Monitoring and closure of the toe drain is described in the Durango Long Term Surveillance Plan.

Settlement Monitoring

Because consolidation settlement of relocated tailings used to construct the Durango disposal cell was a concern relative to potential cover cracking, settlement plates were installed to monitor settlement of the cover of the cell. Results of monitoring of settlement plates indicated that actual measured settlements were much less than predicted by consolidation theory and that cover cracking from settlement would not be a problem. Settlement findings from the Durango site confirmed findings of the test embankment/settlement study performed on the Ambrosia Lake site.

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Falls City, Texas

Site Description

The Falls City disposal site is located in Karnes County, 46 miles (74 kilometer) southeast of San Antonio and approximately eight miles (13 kilometers) southwest of Falls City, Texas. The site is approximately 231 acres (93 hectares).

Prior to the commencement of remedial activities, the Falls City processing site contained six tailings piles and one pond containing residual radioactive material. The selected approach to remedial action was to consolidate all tailings into a single embankment on a parcel of land where the majority of tailings material occurred. All other tailings piles and other windblown contaminated material was moved to this embankment.

Cell Dimensions

The Falls City disposal cell covers approximately 127 acres (51 hectares) and was constructed above

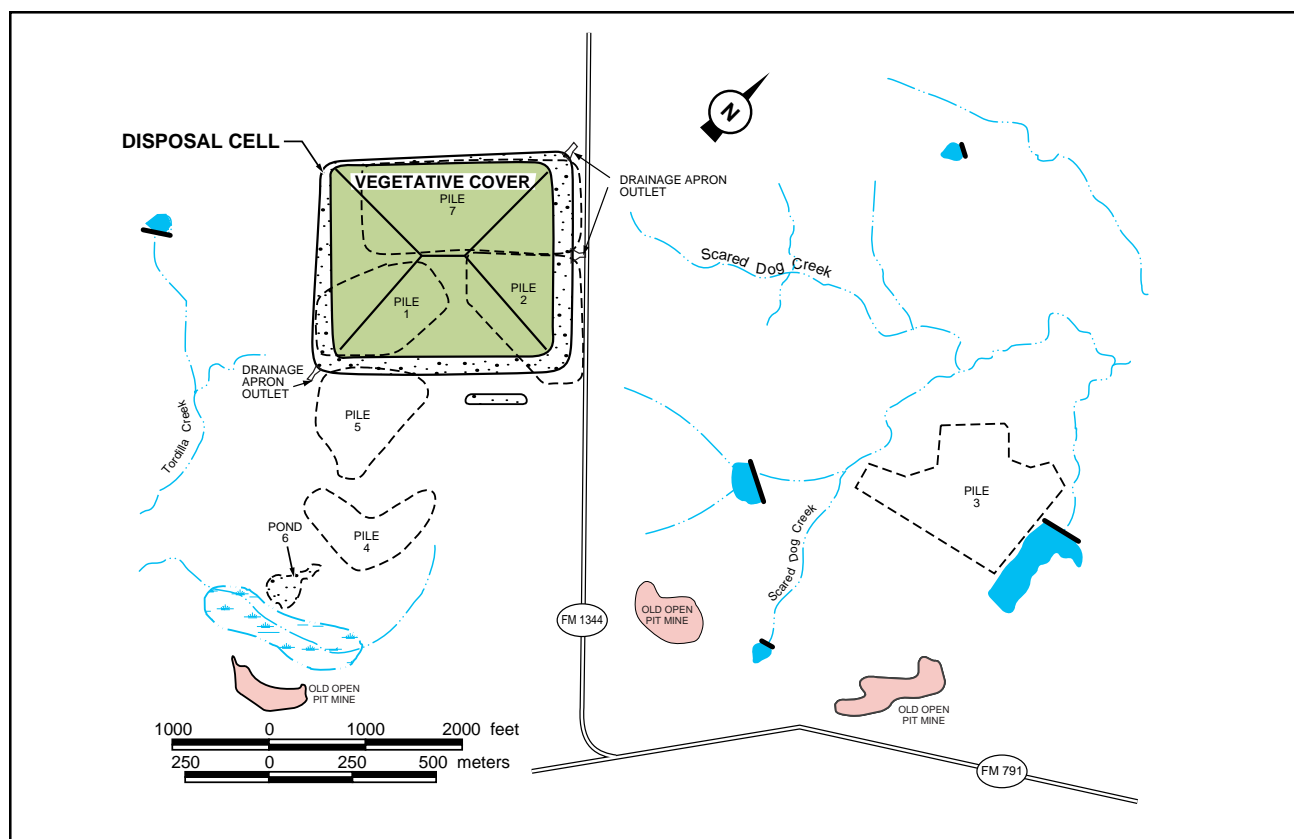
ground. It is rectangular in shape, and is 2,600 feet (790 meters) long and 2,200 feet (670 meters) wide. The embankment rises an average of 37.5 feet (11.5 meters) above the surrounding terrain.

Site Specific Cell Design Features

Vegetative Soil Cover

A vegetated soil cover was designed and constructed for the topslopes of the embankment because of the unavailability of durable rock at or near the site and the large area of the embankment topslope. The closest available rock source, used for riprap for the side slopes, was the Marble Falls Quarry, located approximately 150 miles (240 kilometers) to the north of the site. The cost of transporting and placing rock for the top slopes was considerably more expensive than the design and construction of a vegetative cover.

The vegetated soil cover consists of (from top to



bottom) 6 inches (15 centimeters) of topsoil, and a 30-inch thick (76 centimeters) silty clay layer of growth medium. The purposes of the growth medium are to promote evapo-transpiration of water, reinforce the topslopes, reduce rainfall infiltration into the tailings and contain the root zone of the grassy vegetated surface. Grasses planted on the top slopes are anticipated to require no maintenance. Review of weather data for the Falls City area indicated that rainfall amounts and other climatic conditions would be sufficient to sustain adequate vegetation for erosion protection.

Test Embankments for Settlement Measurement

Similar to the cell at the Ambrosia Lake site, the Falls City cell had a considerable thickness of wet, soft tailings slimes that would be loaded by placing additional tailings from three nearby piles and one pond onto the three piles that would form the disposal cell. The issue of predicting post-construction settlement and differential settlement of the built-up tailings embankment was of great concern. Cracking of the radon barrier layer might occur if post-construction differential settlements were excessive.

Prior to construction of the tailings embankment, two test embankments were constructed directly on the existing tailings pile and displacement monuments were installed and measured. The purpose of the displacement monuments was to record the field settlement characteristics that would enable the UMTRA designers to back-calculate the soils parameters required for the prediction of post-construction settlement. Locations of the test embankments were selected where the potential cracking of the radon barrier layer might occur based on preliminary settlement analysis using laboratory consolidation test results. The heights of the test embankments were adequate to model the final disposal embankment. Based on measured settlement of the two test embankments, it was concluded that the predicted post-construction full-scale pile settlements were much smaller than the post-construction settlement prediction based on the laboratory test data.

With the back-calculated tailings consolidation parameters based on field-testing, a reevaluation of the full-scale post construction settlement and potential for radon barrier cracking for the disposal embankment was made. It was concluded that there would be no cracking of the radon barrier layer.

Naturally Occurring Uranium Ore Left On Site

The original mill was built at this site because of the amount of naturally occurring ore in this area. The ore was pit mined since it was located at or near the ground surface. The remaining, unmined, low economic value, uranium ore at the former processing site was extensively characterized by UMTRA project personnel to distinguish it from the residual radioactive material that was remediated by the subcontractor.

As a result of characterization studies, there are small amounts of naturally occurring uranium ore left in place inside the disposal site perimeter fence and on the remediated former processing site.

Site Surface Runoff Pattern

The location of the three former tailings piles that formed the basis of the disposal cell location are located on top of a local, natural surface water divide. By leaving the disposal cell on this divide, the impact to the cell design from the surface water sheet flow from a probable maximum precipitation event is minimized.

The surface drainage from the disposal cell and the remediated processing site and windblown areas originally formed the headwater collection area for Tordilla Creek and Scared Dog Creek located to the southwest and northeast of the disposal cell. The final surface configuration was returned to an elevation compatible with the original surrounding terrain and recontoured to continue to promote surface drainage toward both creeks.

Frost Barrier Layer Not Needed

A frost barrier layer was not considered necessary for the Falls City disposal cell to prevent damage to the radon/infiltration barrier by freeze-thaw. Regardless, the radon/infiltration barrier on the top slope area has significant frost protection from the growth medium layer.

Placement of Geotextile Barrier Outside of Disposal Cell

Seepage was encountered on the tailings during reshaping in a small area of the side slope near the southeast corner of the tailings embankment. A geotextile fabric layer was placed over tailings slimes that were exposed during excavation. The geotextile provided subgrade stability required to achieve the specified compaction for the radon/infiltration barrier. The radon/infiltration barrier was designed to divert the seepage downward through the tailings below the radon/infiltration barrier. The completion report contains details of the location of the seepage area and the geotextile treatment.

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Grand Junction, Colorado

Site Description

The remedial action approach for this site was to remove all tailings and other contaminated material from the former Climax uranium mill site and the adjacent State Repository in Grand Junction and consolidate these materials at the Cheney disposal site 17 miles (27 kilometers) to the southeast. The Cheney disposal site covers approximately 360 acres (146 hectares) of land.

Cell Dimensions

The stabilized tailings embankment was sized to contain approximately 4.4 million cubic yards (3.4 million cubic meters) of tailings and contaminated material. The Cheney disposal cell covers 94 acres (38 hectares), is roughly rectangular in shape and is approximately 2,400 feet long (730 meters) by 1,800 feet wide (550 meters). The embankment rises a maximum of 40 feet (12 meters) above the surrounding terrain, and it is approximately 70 feet (21 meters) deep from its highest to its lowest point.

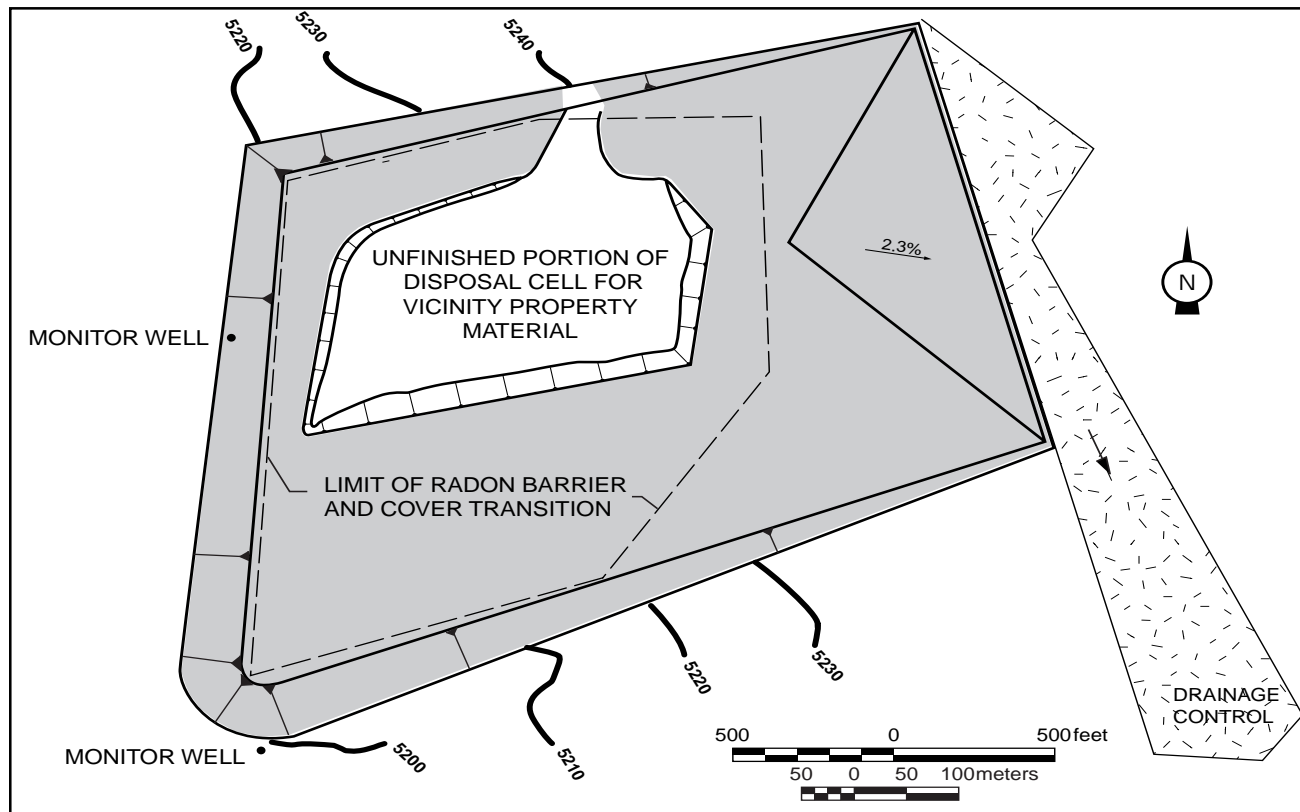
Site Specific Cell Design Features

Siting of the Disposal Cell at Cheney

The selection of the Cheney site as the preferred disposal area was a result of a selective screening process of several potential sites including in-place stabilization at the processing site. The public and local government agencies also participated actively in the site selection process resulting in a determination that the tailings should be stabilized at the Cheney site.

Configuration of the Cheney Cell

During the preliminary design phase, a partially below-grade disposal embankment was initially proposed based on the site characterization information available at the time. The initial design concept was for a disposal cell that extended a maximum height of 50 feet (15 meters) above and approximately 20 feet (6 meters) below the surrounding terrain. However, further site character-



ization discovered water-bearing paleochannels in the alluvial foundation soils. Thus, the ability of the disposal cell design to comply with Environmental Protection Agency ground water standards was questioned. These paleochannels are ancient buried channels that carry small amounts of water on a seasonal basis in a saturated zone approximately 3.5 to 7 inches (10 to 20 centimeters) thick.

As a result of the paleochannel discovery, substantial site re-characterization, including deep borings, was carried out. A total of approximately 130 boreholes, 134 test pits, 1,200 linear feet (360 meters) of test trenches, 100,000 linear feet (30,500 meters) of subsurface geophysical survey lines and numerous field and laboratory hydrologic tests were performed to locate additional paleochannels in the vicinity of the disposal cell site.

A modified disposal cell footprint was located west of the originally selected footprint to avoid the known paleochannels. The new site is bounded by paleochannels. The characterization of this new site showed no evidence of shallow alluvial ground water. To meet Environmental Protection Agency ground water standards, the new site design placed the base of the cell excavation sufficiently deep into weathered and unweathered Mancos shale to prevent lateral flow of any tailings leachate into the near surface alluvium. The bottom of the cell was placed below the bottom elevation of the surrounding paleochannels to limit the potential for subsurface pore water flow from the cell into the paleochannels. As a result, the foundation of the disposal cell extends 60 to 70 feet (18 to 21 meters) below the surrounding terrain.

Side Slopes Consisted of Clean Fill Dikes

The Cheney disposal embankment was the first UMTRA site where the side slopes of the cell consisted of low permeability, clean fill barriers constructed of excess materials from the disposal cell excavation. These barriers act like earthen dams to contain tailings materials inside the disposal cell.

The reason for this side slope design was to make use of the excess material that was excavated from the disposal cell foundations. As stated above, the

ground water strategy necessitated excavating a disposal cell foundation that had a bottom elevation lower than the elevation of the paleochannels that were identified in the vicinity of the disposal cell. This created a very large volume of excavated material, primarily Mancos shale. Rather than spoil this material in above ground piles at the disposal site, it was decided to use this low permeability material in the construction of the disposal embankment side slopes. The use of the material in the construction of the disposal embankment sideslopes also provided the following advantages: (1) the thick, low permeability dikes provided additional hydrologic isolation of the tailings; (2) the construction of the side slopes was simplified since the radon-infiltration barrier and the associated bedding layer was eliminated from the side slope design; and (3) long-term problems (visual aesthetics and erosion control) associated with large above ground spoil piles were avoided. These clean fill barriers were also extended below the original ground surfaces to function as an additional hydrologic barrier preventing potential flow from paleochannels into the cell. The riprap used on the top and side slope of the cell, as well as the drainage channels, also came from required excavations.

Geochemical Attenuation Layer

Laboratory geotechnical testing and analysis were performed to determine the requirement for a geochemical attenuation layer placed at the base of the disposal cell excavation. The purpose of such a layer would be to capture contaminants exiting the base of the tailings. However, the test results and analysis indicated that placing a geochemical attenuation layer did not provide substantial differentiation between tailings leachate and natural ground water, which also had traces of uranium. Thus a geochemical attenuation layer was not included in the cell design.

Potential Saturation within Cell

The cell design considered the potential saturation within the cell from two sources of water: 1) transient drainage during the construction stage and

post-construction drainage of fluid from the tailings pore spaces and 2) the long-term infiltration of rain water and snow melt through the cell cover.

The foundation materials had to be sufficiently permeable to prevent the buildup of excess saturation within the cell that could result in lateral flow of tailings leachate into the surrounding alluvium and paleochannels. Variable saturated modeling was conducted during the design stage. The modeling concluded that long-term saturation within the cell would not be significant.

One of the key parameters required for this modeling was an accurate determination of field unsaturated and saturated hydraulic conductivities of the foundation areas. *In situ* Sealed Double Ring Infiltrometer testing was performed on the Mancos shale in the excavated foundation bottom in conjunction with other field and laboratory testing. An exploratory borehole recently completed within the Cheney cell confirmed that there has been no significant leachate buildup at the base of the cell in the four years since construction was completed, even though a portion of the cell remained exposed to direct rainfall.

Vegetative Growth

The growth of volunteer vegetation on the top slope does not currently effect the radon barrier. However, this should continue to be monitored and if necessary controlled.

Unfinished Portion of the Cell

This portion of the disposal cell was left open to receive additional vicinity property material until the year 2023 or until the cell design capacity is reached (up to approximately 500,000 cubic yards [362,000 cubic meters] of vicinity property materials). The cell design for the top cover has been completed and approved by the Nuclear Regulatory Agency, and the approved riprap material has been stockpiled at the site for the closure of the disposal cell.

On-site Paleochannels - Additional Details

The paleochannels that exist in the alluvium overlying bedrock at the disposal site are locations where seasonal or temporary perched water zones may occur. The paleochannels are preferential flow paths for seepage that perch on the low permeability bedrock. Even when flow occurs in a paleochannel, it may not be continuous, since some seepage into the underlying bedrock surface occurs and small flows can dissipate and disappear. The paleochannels were difficult to locate precisely during investigations due to the subsurface location, variability of flow occurrence as a result of seasonal and climatic factors, and similarity of the materials in the paleochannels to adjacent materials.

As stated previously, the disposal cell design avoided paleochannels by siting the cell in a localized bedrock 'plateau' that was identified by numerous test pits, trenches, and borings. The area of the cell footprint also did not contain locations where water was encountered during the siting investigation. One paleochannel was encountered during excavation of the cell foundation; it was designated the 'northwest' paleochannel. The presence of the northwest paleochannel was mitigated by revising the cell footprint and by diverting the paleochannel and its flow around the north side of the cell.

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Green River, Utah

Site Description

The Green River disposal site is located on the former mill and tailings site. The site is located one mile (1.6 kilometers) southeast of the community of Green River.

Cell Dimensions

The residual radioactive material was stabilized on-site. The disposal cell covers approximately five acres (2 hectares), is rectangular in shape, and is 530 feet (162 meters) long by 450 feet (137 meters) wide. It is constructed partially below grade and rises some 40 feet (12 meters) above the surrounding terrain. It is approximately 95 feet (29 meters) deep from its highest to its lowest point.

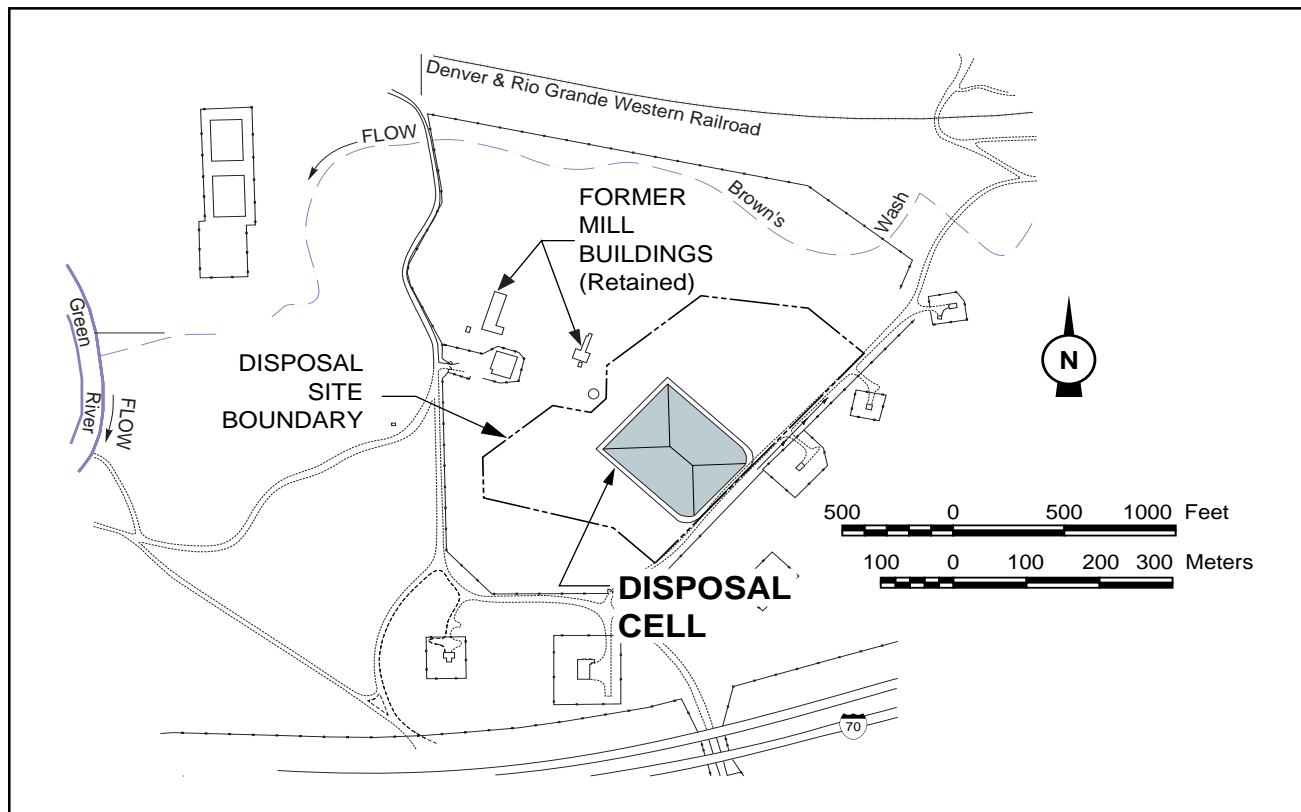
Site Specific Cell Design Features

Cell Performance Monitoring

During the design of the Green River disposal cell, there was concern about the potential for signifi-

cant amounts of transient drainage water draining from the cell. To minimize this potential, it was decided to establish a target for the upper limit on compaction water content of relocated tailings. Placement of relatively dry tailings would limit the amount of water available to drain from the cell as transient drainage.

During construction a significant portion of the relocated tailings was placed at moisture contents that exceeded the target upper water content value. The transient drainage analysis variables were talked about between UMTRA team members and Nuclear Regulatory Commission representatives. The transient drainage analysis had sufficient variability that the desired cell performance could still be obtained with the tailings being placed at moisture contents exceeding the design limit value. The DOE decided that rather than rebuild the disposal cell by removing and re-compacting the tailings materials at a lower moisture content, it would monitor the movement of soil moisture in the completed cell to determine if the actual transient



drainage was within acceptable limits. It was decided to use neutron moisture probe technology for this monitoring. At the time, this was a new application for neutron probe measurements.

Several cased, neutron probe access holes were installed in the completed tailings embankment to serve as access “wells” to monitor moisture variations over time within the cell. Steel well casing was installed to allow a neutron probe to be lowered into the tailings for the purpose of monitoring the location of moisture in the tailings. After unsuccessful attempts to measure the low moisture contents, the casings were sealed and abandoned.

The use of neutron moisture probes for this cell performance monitoring did not succeed for several reasons. The primary reason was because steel casing rather than aluminum casing (as specified by the manufacturer) was used. Project personnel determined that steel casing had to be used because of the difficulty driving the casing into the compacted tailings (which collapsed the aluminum casing), and the length of casing required penetration to a depth in the cell that was greater than could be achieved with aluminum casing. The use of neutron probes to monitor moisture in compacted tailings was adapted from agriculture. In agricultural applications the aluminum tube is driven into the root zone (usually no more than five feet (1.5 meters) deep) to allow researchers to monitor irrigation water movement. The steel casing used at the Green River cell apparently produced too much interference to allow detection of a wetting front in the tailings.

Another factor that may have contributed to the failure of the early model neutron moisture probe used in this application may have been an insufficient wetting front (i.e. not enough differential in moisture content) in the tailings to measure. The tailings were mostly dry sands with very little clay material. Tailings were placed in the cell at less than ten percent moisture content by weight, which indicates that differential moisture contents of 1 or 2 percent may have represented the “wetting” front. Drift of the neutron moisture probe used by

the UMTRA team was much greater than 1 or 2 percent. Why the drift of the probe used was excessive was never satisfactorily determined.

Several monitoring wells were installed around the Green River cell to satisfy State of Utah concerns after failure of the neutron moisture probe monitoring program.

Mill Buildings Left on Site

The community of Green River asked the Department of Energy to leave in place as many buildings as possible for use as a future industrial park. Some contamination was left in the buildings in relatively inaccessible areas under approved supplemental standards.

Gully Erosion Potential

Gully erosion potential exists on the disposal site, but it is not considered to be a significant threat to the disposal cell. The elevation difference from the site to the local drainage bottom (Brown’s Wash) suggests that deep gullies could form over time. However, the small drainage area and the bedrock elevations around the cell are two factors that are expected to prevent any deep gully from reaching the edge of the cell. Furthermore, the riprap key trench constructed around the disposal cell provides protection from erosion that may occur next to the cell. Calculations and other project documents provide additional details regarding stability of the cell against impacts of erosion.

Gunnison, Colorado

Site Description

The Gunnison disposal cell was constructed at Chance Gulch, approximately seven miles (11 kilometers) east of Gunnison, Colorado, on land formerly administered by the Bureau of Land Management.

Cell Dimensions

The 29 acre (11.7 hectares) disposal cell is roughly rectangular 1,300 feet (400 meters) long and 1,050 feet (320 meters) wide. It is approximately 60 feet (18 meters) deep from its highest to its lowest point.

Site Specific Cell Design Features

Site Selection

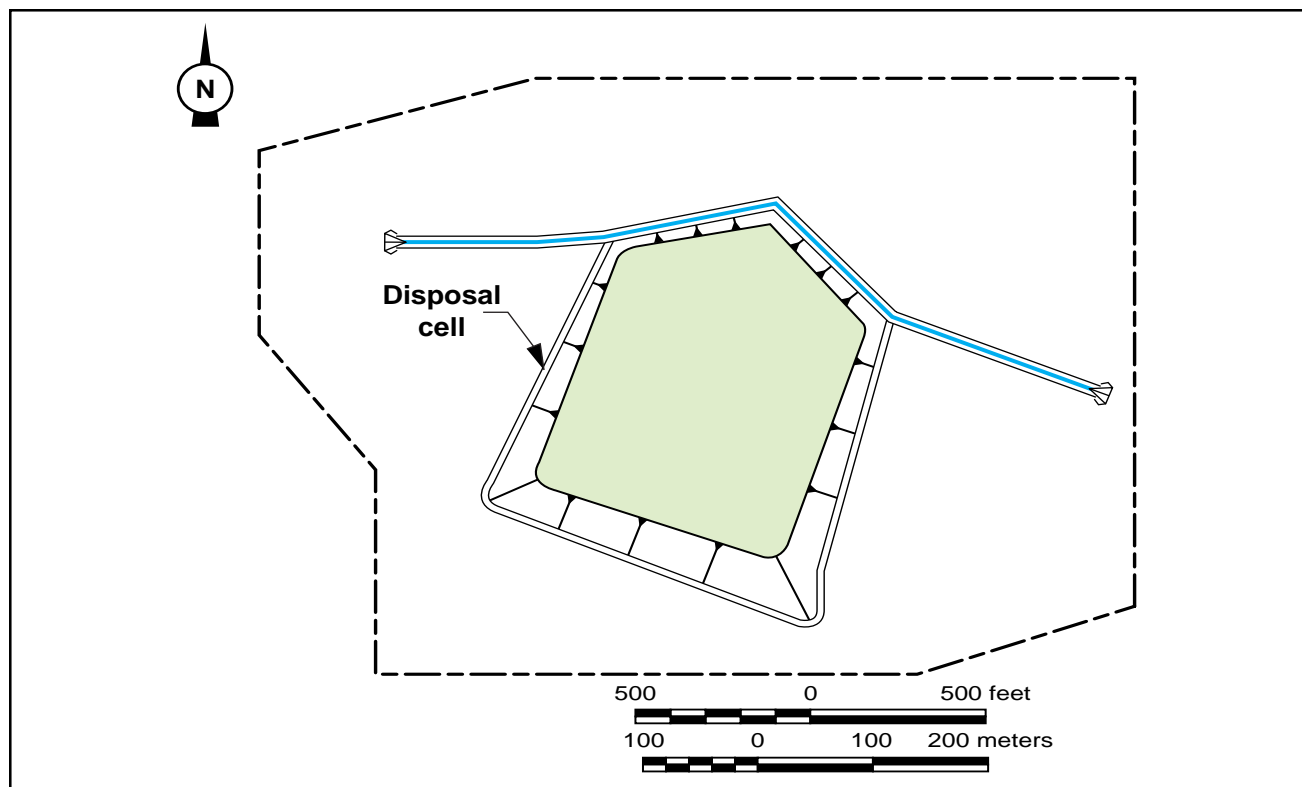
The Chance Gulch disposal site was selected after an extensive regional search for an erosionally stable site. Prior to construction, the natural ground surface at the disposal site was observed to exhibit natural armoring to surface erosion. The existing gully bottoms and steeper slopes had gravel and

cobble armored surfaces. Such surfaces were not present on the gradual natural slopes in the area. Materials excavated from the cell's foundation area were used for site grading rather than using more erodible imported materials.

Like the Grand Junction disposal cell, the Gunnison disposal cell was constructed with massive dikes (i.e. similar to dams) of compacted, uncontaminated materials that underlie the side slopes. The cover system used includes a frost barrier and capillary break layer 6.5 feet (2 meters) thick on the top slope. Because the frost barrier is very thick, vegetative biointrusion was considered to be unlikely to require rapid response, and so could easily be handled by long-term surveillance and maintenance personnel.

Potential Future Considerations

Soon after construction of the Gunnison disposal cell was completed, evidence of water collecting in and overflowing from the apron key trench was observed at the southeast corner of the cell. In-



spection of this seepage indicated that it was rainfall runoff water collecting in and overflowing from the apron key trench. This condition is not considered to be detrimental to performance of the cell, except in the unlikely event that gully erosion would occur.

Maintenance Issues

In late 1998, a relatively dense plant community was established in the overflow area which would help resist erosion, in addition to the natural erosion-resistant behavior of the materials themselves (as discussed above). The Long-Term Surveillance Program will monitor vegetative growth on and around the Gunnison disposal cell.

Potential adverse effects on cell performance caused by changes in human activities, such as the nearby County landfill, were not included in the cell design. Erosion protection and ditch sizes were based on existing watershed areas that drain towards the disposal cell. It is possible that landfill earth moving activities could change the pattern of rainfall runoff and flow concentration onto the Gunnison UMTRA site. Since such changes are a possibility, the long term surveillance plan for this site indicates that County landfill activities north of the UMTRA disposal site should be monitored to ensure that surface water drainage patterns are not changed.

The Gunnison Long Term Surveillance Plan document describes a monitoring program for the riprap rock placed on the disposal cell as a preventative measure. During quarrying of this rock, a system of fine, very tight, fractures was observed in some samples of the rock produced. The project was unable to demonstrate to the Nuclear Regulatory Commission that the fractures would or would not result in splitting of some portion of the particles, leading to a reduced effective particle size in the riprap layer. To evaluate the potential for this reduction of rock size, the monitoring program was developed and included in the surveillance plan.

Lakeview, Oregon

Site Description

The residual radioactive materials were relocated to a disposal site on property owned by John Collins, approximately seven miles (11 kilometers) north-northwest of the Lakeview former mill and tailings site. The Collins Ranch disposal site is 40 acres (16.2 hectares) in size.

Cell Dimensions

The disposal cell is roughly semicircular in shape, and is constructed partially below grade against the southwest slope of a hill. It is approximately 1,050 feet (320 meters) long by 800 feet (240 meters) wide. It rises some 40 feet (12 meters) above the surrounding terrain and is approximately 75 feet (23 meters) deep from its highest to its lowest point.

Site Specific Cell Design Features

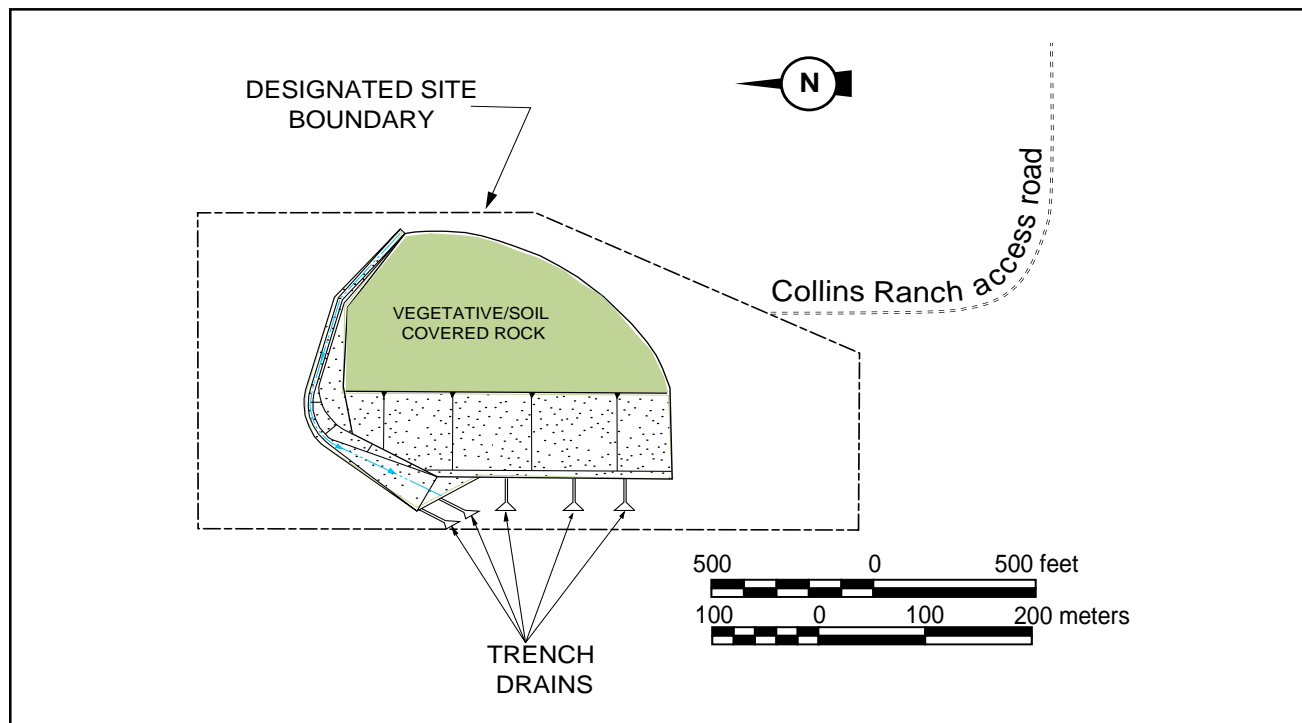
Erosion of the Cell's Top Slope Material

The riprap erosion protection layer on the Lakeview disposal cell was covered by a thin layer of soil

and planted with grasses. Erosion of this thin soil layer is not an issue regarding the long-term stability of the cell. This soil layer was placed for aesthetic reasons and is not an essential design feature of the erosion protection system for the Lakeview disposal cell.

Cover Design Considerations

Because of the rather mild weather in the Lakeview area, and the state of design understanding at the time that this cell was designed, the cover design for this cell did not include a frost barrier layer or a biointrusion barrier. Also, the radon barrier soil is different than soils used for other UMTRA radon barriers (low specific gravity, silty, etc.). The radon barrier soil was not tested for freeze-thaw effects on permeability or radon diffusion. After completion of the Lakeview disposal cell, testing done for the Maybell, Colorado site indicated that permeability of silty sand soil amended with bentonite clay could potentially increase due to freeze-thaw action. It is not known if a similar freeze-thaw induced soil-structure versus soil-moisture interaction could occur in the radon barrier layer at



the Lakeview site. The Long Term Surveillance Program will be monitoring this issue.

Subsurface Drains

Subsurface drains were installed for the rock-filled apron and ditch outlet key trenches after erosion was observed at discrete locations along the outside edges of the trenches. Rainfall runoff from the disposal cell side-slopes collected in the apron trenches and overflowed from the trenches onto the adjacent ground surface creating erosion rills. Soils adjacent to the trench were relatively erodible, so experience at this site was not assumed to be applicable to all sites, although a few other sites were determined to require similar apron trench drains.

Maintenance of Riprap

Quality and long-term resistance to weathering of the riprap rock used at the Lakeview site has been a conundrum that started during construction of the disposal cell. To provide added assurance that potential future weathering and break down of riprap rock at this site would not adversely affect performance of the cell, the thickness of the riprap layer was increased over that indicated by design calculations.

Before any additional rock is placed on the top or side slopes of this site project designers have recommended that the following two key factors be considered: a) the conservatism that was included in the riprap layer thicknesses actually placed during construction, and b) the past experience with durability of local rock sources in nearby facilities. Layer thicknesses used for the top slope and side slope riprap at the Lakeview site are four times and two times thicker, respectively, than the minimum required design layer thicknesses that accommodate the particle sizes. The additional thickness helps to compensate for any breakdown of riprap pieces on this cell.

The quality of local basalt quarry rock sources was found to be especially difficult to judge using typical UMTRA project procedures. Geothermal and other local conditions have likely affected the long-

term durability of the local basalt rock. For example, two of the petrographic examinations of the Pepperling quarry rock resulted in different recommendations regarding the expected long term behavior of riprap produced from the rock. Additionally, observations of broken or decomposed rock particles could not determine if the original particles were sound in appearance, or particles that were produced from poor quality zones that were inadvertently placed with the approved riprap.

Lowman, Idaho

Site Description

The Lowman residual radioactive material was stabilized in place at the former mill and tailings site. The site covered 37 acres (15 hectares) and is located one-half mile (0.8 kilometer) northeast of the town of Lowman, Idaho, within the Boise National Forest.

Cell Dimensions

The disposal cell is roughly semicircular in shape and covers 8.2 acres (3.3 hectares). It is approximately 950 feet (290 meters) long by 480 feet (145 meters) wide, and is 30 feet (9 meters) deep from its highest to its lowest point.

Site Specific Cell Design Features

Large Rock Placed in Gully

Large rock pieces placed in the gully northwest of the Lowman cell are not critical to the erosion protection layer design for the disposal cell. These

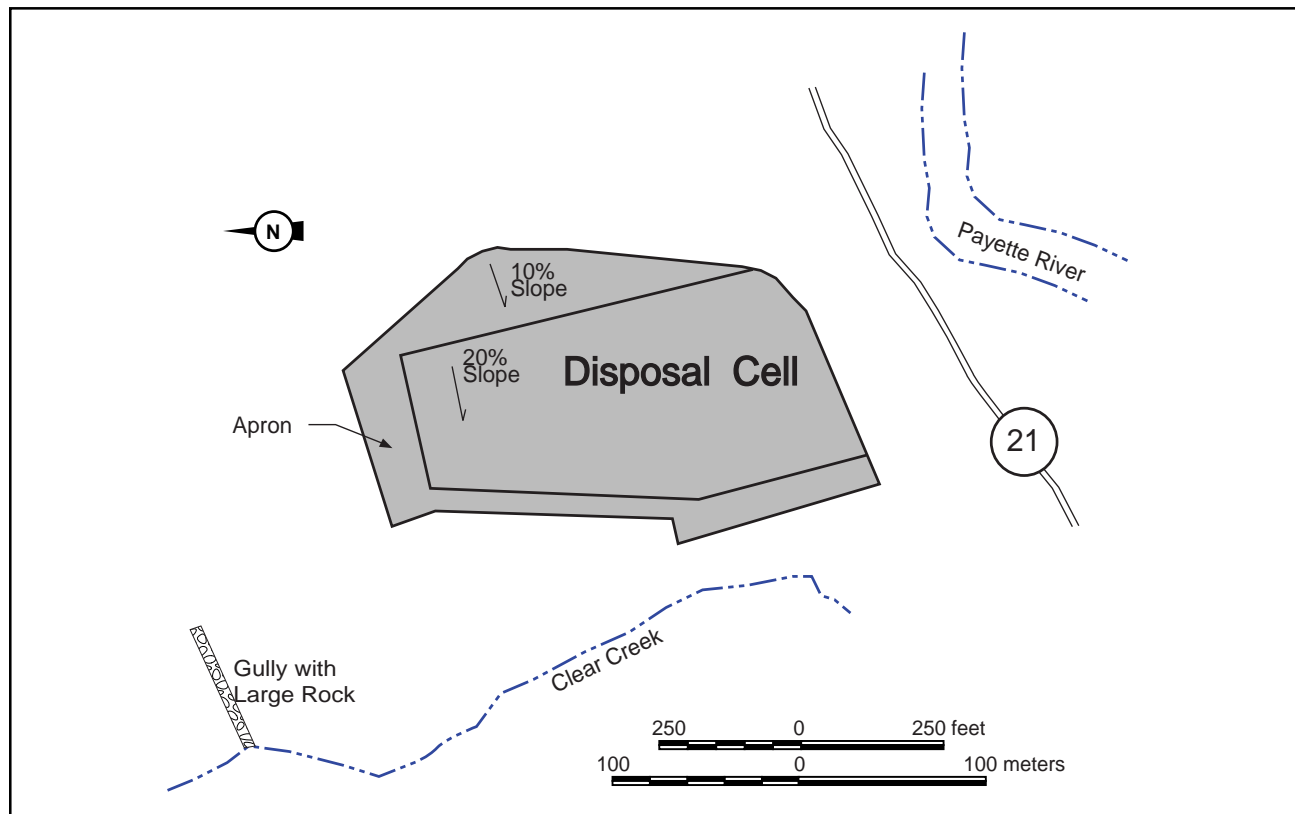
rocks are for hydraulic energy dissipation in the gully, therefore they are not required to meet the quality and rock soundness criteria for the 200-1000 year design life required by UMTRA cell design procedures. This rock was placed in the existing gully to reduce the risk of further gully initiation and for disposal of excess oversize rock.

Gravel Placed Along Edges of Rock Outcrop

Gravel placed along edges of the rock outcrop located near the riverbank was also placed to reduce the risk of new gully initiation. Again, the design basis for the use of this gravel was not the UMTRA 200-1000 year design life.

No Frost Barrier in Cover

Design analyses performed for the Lowman disposal cell indicated that a frost barrier was not required by the remedial action plan to protect the entire thickness of the radon/infiltration barrier from potential effects of freeze-thaw.



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Maybell, Colorado

Site Description

The Maybell disposal cell is located approximately 25 miles (40 kilometers) west of the town of Craig, Colorado. The site covers 110 acres (44.5 hectares). There are several open pit mines and waste rock piles in the surrounding area.

Cell Dimensions

The residual radioactive material was stabilized in place. The cell covers approximately 66 acres (26.7 hectares) and rises some 30 feet (9 meters) above the surrounding terrain. The disposal cell shape is roughly triangular, and is 2,600 feet (790 meters) long and 1,700 feet (520 meters) wide. From its highest to its lowest point is approximately 75 feet (23 meters).

Site Specific Cell Design Features

Rob Pit Pile Erosion Protection

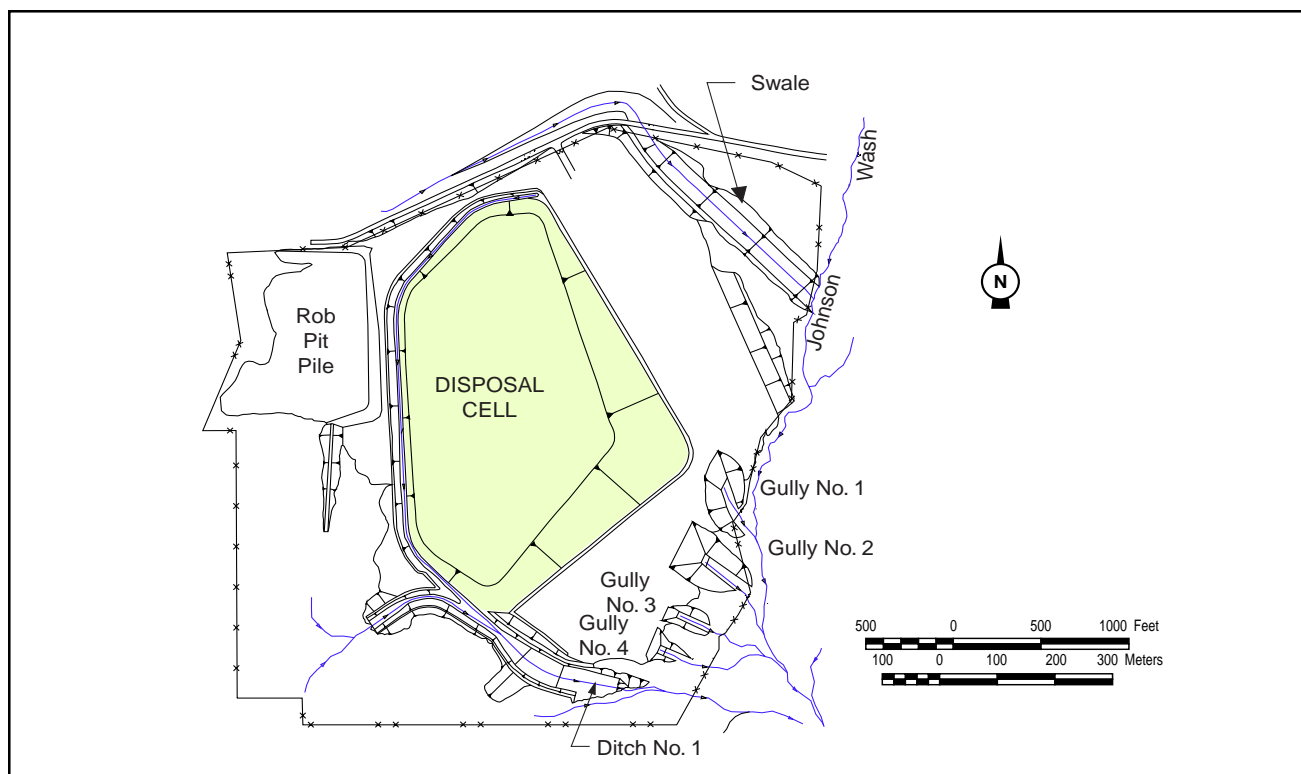
The Maybell tailings pile was stabilized in place, by consolidating the size of the existing pile, and

placing excavated materials, wind blown materials, and vicinity property materials on top of the pile.

Observations of existing soil piles adjacent to the site indicated that they consisted of silty and sandy materials that were highly prone to erosion. These nearby piles were determined to be so erodible that erosion protection riprap materials were placed on the nearby Rob Pit pile side slopes, located west of the disposal cell, to protect against potential sediment blockage of the disposal cell's main drainage ditch.

Bentonite Amended Cover Material

To provide a low permeability radon barrier layer for the Maybell cover, it was determined that the on-site silty sand would have to be amended with seven percent by weight of powdered, Wyoming bentonite clay. Considerable analysis and testing were performed to determine if these bentonite amended soils would be resistant to freeze-thaw cycles. Since the laboratory analyses were incon-



clusive, it was decided to include a frost protection layer rather than proceed with another round of testing. It was determined that the silty sand used on this site, when amended with bentonite, had some resistance to the detrimental effects of freeze-thaw cycles; however, the data did not indicate that the reliability on this resistance was adequate for design, and a frost protection layer was still required. Unamended silty sand from the same nearby soil pile used to produce radon barrier material was used to construct the frost protection layer.

Some erosion is expected to occur at the outlet of the main ditch (ditch number 1). The key trench for the outlet of this ditch, which is 10 feet (3 meters) deep, was designed to allow erosion and adjustment of the riprap by undercutting without impacting the performance of the ditch.

Drainage Ditches and Erosion Protection Rock

Four gullies, tributaries to Johnson Wash, are located just southeast of the Maybell disposal cell. Gully number two was determined to have predated the uranium processing activities on this site, and early aerial photographs indicate that this gully extended beneath the area of the present Maybell tailings pile. Design calculations indicated that potential headward growth of these gullies to the toe of the Maybell cell was unacceptable, and residual radioactive material in gully number two had to be covered and maintained within the disposal site.

Large size riprap was placed in these four gullies to protect against headcutting of the existing gullies towards the toe of the disposal cell.

Unlike the four gullies located southeast of the cell, two swales located north and northeast of the embankment are not critical to the cell as flow diversion ditches. This is because the cell's main diversion ditch (ditch number 1 on the drawings) was designed to divert all of the flow from the upslope drainage area without any flow by the north ditch. This is the primary reason the main diversion ditch appears so large. The two swales intercept surface water runoff from the northern upland areas and divert the flow around the cell into Johnson Wash. Because of the small drainage areas and their distance from the disposal cell, erosion protection materials were not placed in these two swales. As a result, some erosion is expected in these swales over the long term but should not, by itself, impact the embankment performance.

Mexican Hat, Utah

Site Description

The Mexican Hat disposal site is located on Navajo Nation land at Halchita, Utah, approximately 1.5 miles (2.4 kilometers) southwest of Mexican Hat, Utah.

Cell Dimensions

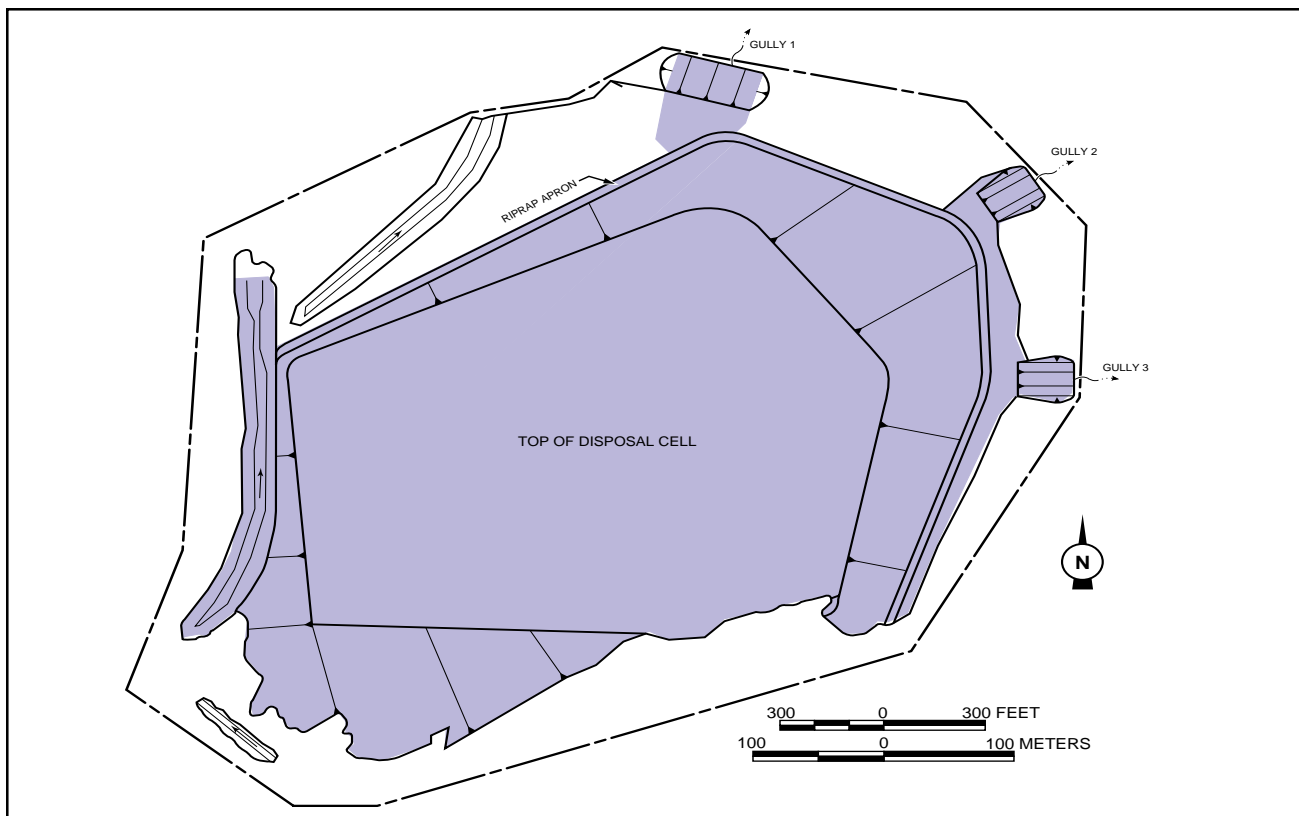
Approximately 2.5 million cubic yards (1.9 million cubic meters) of residual radioactive material from the two Mexican Hat tailings piles were consolidated in place. In addition, approximately 928,000 cubic yards (710,000 cubic meters) of residual radioactive material was moved from the Monument Valley, Arizona UMTRA site to the cell. The above ground disposal cell is roughly pentagonal in shape and covers approximately 68 acres (27 hectares). It abuts a steep ridge to the south and rises to a height of 50 feet (15 meters) above the surrounding terrain to the north, east, and west. The cell is approximately 2,700 feet (820 meters) long and 1,700 feet (520 meters) wide. It

is approximately 50 feet (15 meters) deep from its highest to its lowest point.

Site Specific Cell Design Features

Bentonite Amended Radon Barrier

Available soils in the vicinity of the Mexican Hat site are predominately silty sands. These soils were tested and found that they could not meet the permeability requirements for the radon barrier layer. To correct this situation it was decided to mix commercially available powdered bentonite clay with locally available soils. The resulting soil-bentonite mixture was used to construct the radon barrier for the Mexican Hat disposal cell. This was the first site where a pug mill was used to mechanically mix the soil and powdered bentonite clay to provide a uniform, reproducible mixture each day of production. This process was very important in producing a uniformly low permeability cover layer across the entire disposal cell.



The active clay mineral in powdered bentonite clay that produces low permeability is a smectite clay mineral called montmorillonite. The product that is commercially known as Wyoming bentonite has approximately 70 to 80 percent of this active montmorillonite clay ingredient. A Utah “bentonite” source, referred to as Redmond clay, was used to produce the radon barrier material for the Mexican Hat site. This Redmond clay was locally available and much less expensive than Wyoming bentonite. However, it contains less montmorillonite than a typical Wyoming bentonite, and more of it had to be used to prepare a suitable soil-bentonite mixture. Cost analyses indicated that using the Utah bentonite in the soil mixture provided the most cost-effective means of achieving the permeability requirements for the cell design.

No Frost Protection Layer in Cover

The cover system designed for the Mexican Hat site does not include a frost protection layer. A frost protection layer was not included for two reasons. First the depth of anticipated frost penetration at Mexican Hat site was not estimated to be great, and second, published research in the geotechnical literature indicated that the permeability of the bentonite amended silty sand soil mixture would not be affected by freeze-thaw cycles. Later research and testing performed in association with the design of the Maybell, Colorado site indicated that although the permeability of clean sands mixed with bentonite are not significantly affected by freezing and thawing, the permeability of some silty sands mixed with bentonite may be affected if they are “hard” frozen.

Cell Tied into South Ridge

The upper edge of the riprap erosion protection for the tailings embankment is tied into a sandstone ridge located south of the disposal cell. At this location, there is a wide band of Type B riprap (which has particle diameters of eight inches [20 centimeters] or less) at the contact with the ridge. Some accumulation of spalling and gully debris from the ridge on to the top of the embankment is anticipated, although it is not expected to be detrimental to the function of the erosion protection

layer.

Apron Depth Varies

The depth of the key trench varies beneath the riprap apron at the toe of the side slopes on the north and south sides of the tailings embankment. This depth variation occurs because the apron is keyed into competent bedrock that is encountered at varying depths around the perimeter of the disposal cell. Erosion gullying beyond the disposal cell’s apron is expected to a degree, but estimates of erosion rates indicate that it should not be a threat to the performance of the embankment.

Sandstone in North Arroyo and West Ditch

Rock quality (with respect to hardness and resistance to weathering) of the large sandstone boulders placed in the north arroyo and west of the collection ditch was not an erosion protection design issue. The rocks are not a part of the disposal cell’s riprap erosion protection layer; rather they are intended as sacrificial energy dissipating rock that is not critical to the performance of the disposal cell.

Natural Seepage Around Cell

Prior to construction at the Mexican Hat site, natural seeps were observed by UMTRA geologists in the North Arroyo, Gypsum Wash and the gully southeast of the disposal cell site. The presence of these seeps also was indicated in aerial photographs that predated the establishment of uranium milling activities at the Mexican Hat site. The water quality of these seeps was tested and no significant correlation of chemical constituents in the seep water with the tailings pore water chemistry was observed.

Naturita, Colorado

Site Description

The Naturita disposal site is located on land formerly owned by Umetco Mineral Company. The Department of Energy acquired the disposal site land via valuable consideration on June 16, 1997. The sale consisted of 26.6 acres (10.8 hectares). The disposal site is called the Upper Burbank Repository and is located approximately 15 miles (24 kilometers) northwest of the town of Naturita, Colorado. The cell was constructed approximately north of and adjacent to Umetco's UMTRA Title II disposal cell.

Cell Dimensions

The Upper Burbank disposal cell is located in the north end of a rock quarry developed by Umetco. Being a quarry pit, the site is essentially a large hole excavated into solid bedrock along the southern rim of Club Mesa with rock slopes on three sides. The cell occupies 10 acres (4.1 hectares) and is roughly rectangular in shape. It rises some 80

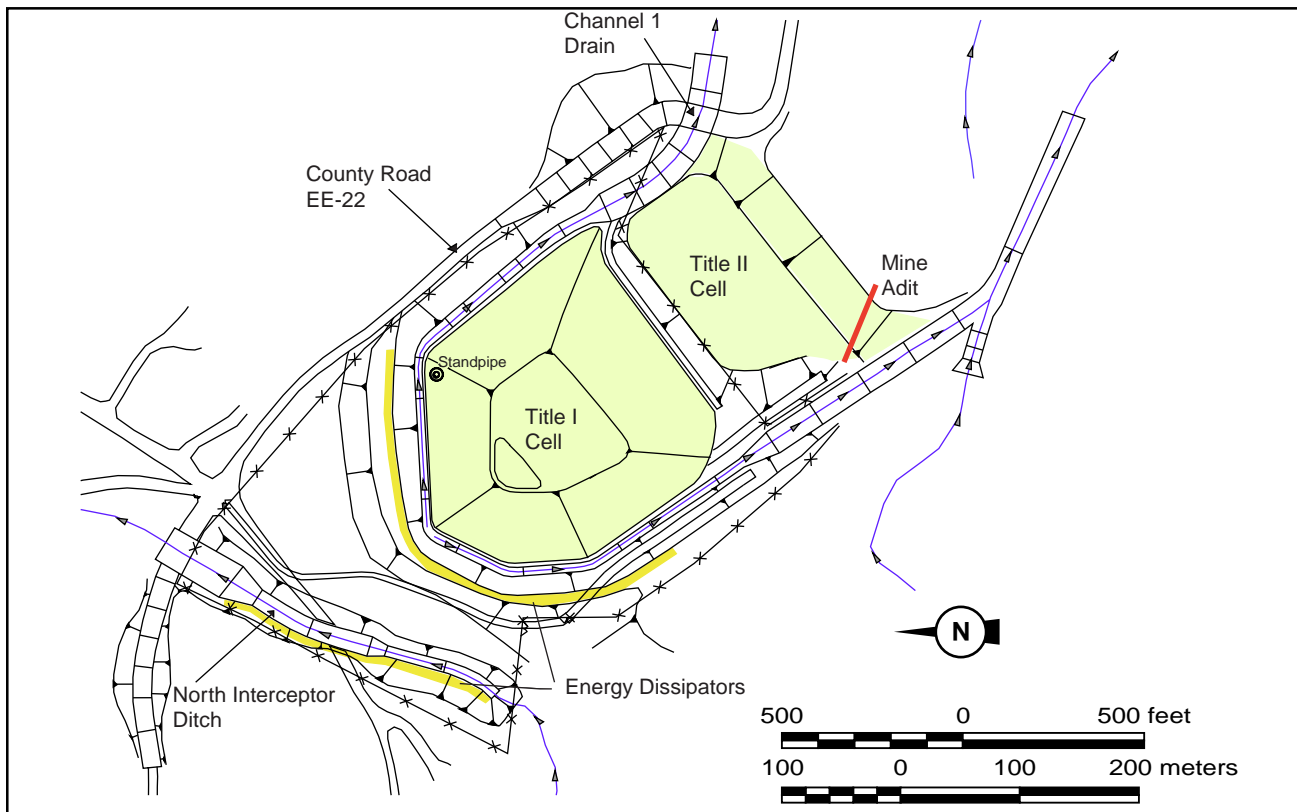
feet (24 meters) above the bottom of the pit, and is approximately 830 feet (253 meters) long and 820 feet (250 meters) wide.

As part of the purchase price of the Upper Burbank site, the Umetco Minerals Company also provided the remedial action plan and final design for the disposal cell and made required design changes during construction.

Site Specific Cell Design Features

North Interceptor Channel

The interceptor channel north of the disposal cell is a critical design element. The channel diverts runoff from upland areas and thereby reduces erosion protection requirements for the cell. It should be maintained clear of debris and blockage. If future mining activities significantly increase the drainage area contributing rainfall runoff to the north interceptor channel, a reevaluation of its hydraulic design should be performed.



Buffer Zone between Title I and Title II Cells

A buffer zone consisting of a compacted soil dike and a ditch were designed and constructed for this site to separate the Title I and Title II disposal cells. The compacted soil dike was keyed into shale bedrock, and compacted into the northern slide slope and toe area of the existing Title II disposal cell.

Side Wall Clay Liner

Since the Upper Burbank disposal cell was constructed in a preexisting rock pit, there was some concern among project designers that leachate from the UMTRA cell could seep laterally into the bedrock sidewalls. Therefore, a side wall clay liner was constructed below grade to block lateral flows into or out of the tailings from the adjacent bedrock. Computer programs were used to model seepage into and out of the disposal cell. This modeling predicted that very little, if any, water buildup would occur at the base of the cell.

Standpipe

A polyvinyl chloride standpipe was installed near the northeast corner of the disposal cell to detect rainfall or transient drainage water buildup that might occur at the bottom of the cell during construction. This standpipe was left open at the request of the State of Colorado. Computer modeling predicted that very little, if any, water buildup would occur at the base of the cell during its design life. The standpipe will be monitored under the Long Term Surveillance Program.

Sandstone Used for Energy Dissipation

Sandstone rocks (sized at a 50 percent diameter of 36 inches [90 centimeters]) for energy dissipation purposes were placed upgradient of the drainage ditches around the disposal cell and also up gradient of the diversion channel for energy dissipation purposes. With these walls of sandstone rock reducing the energy from sheet flow surface runoff, available smaller rock could be utilized in the construction of the drainage ditches and the diversion channel. The lesser quality sandstone ledge rock from the Umetco borrow site was used due to the

lack of a nearby source of larger rock sizes with high durability rating scores. Excess, large size rock from the Cheney (Grand Junction) disposal site was imported for protection of limited, critical areas where the sandstone rock could not be used. The Cheney rock is basalt and is distinguished from the sandstone by its dark gray color. (The Cheney disposal site rock had previously been shown to have adequate durability and was available in adequate quantity without approval as a new source.)

Mine Adit under Title II Cell

An adit is located under the west edge of the Umetco Minerals Company's Title II cell, but it does not extend under or near the UMTRA Title I cell. This adit was originally constructed to drain subsurface waters away from the base of the Burbank Pit so that Umetco could excavate the pit as a source of sandstone rock.

Drains Not Designed for Probable Maximum Flood

Reduced design criteria were used for the last (most downgradient) segment of Channel Number 1 because the potential for adverse impacts to the Title I cell is very small. The last segment of Channel Number 1, (i.e., the low flow section) is designed for a 25 year storm, not the probable maximum flood. The last segment of Channel Number 1 is down gradient of the Title I cell, and the beginning of the last segment is located approximately 200 feet (60 meters) from the intersection with county road EE22.

Rifle, Colorado

Site Description

The Rifle disposal cell is located at the Estes Gulch site approximately seven miles (11 kilometers) north of the town of Rifle, Colorado.

Cell Dimensions

The cell occupies 71 acres (28.7 hectares), is roughly triangular in shape and is constructed partially below grade. It rises 76 feet (23 meters) above the surrounding terrain, and is approximately 3,200 feet (975 meters) long and 2,900 feet (880 meters) wide. It is approximately 87 feet (26 meters) from its highest point to its lowest point.

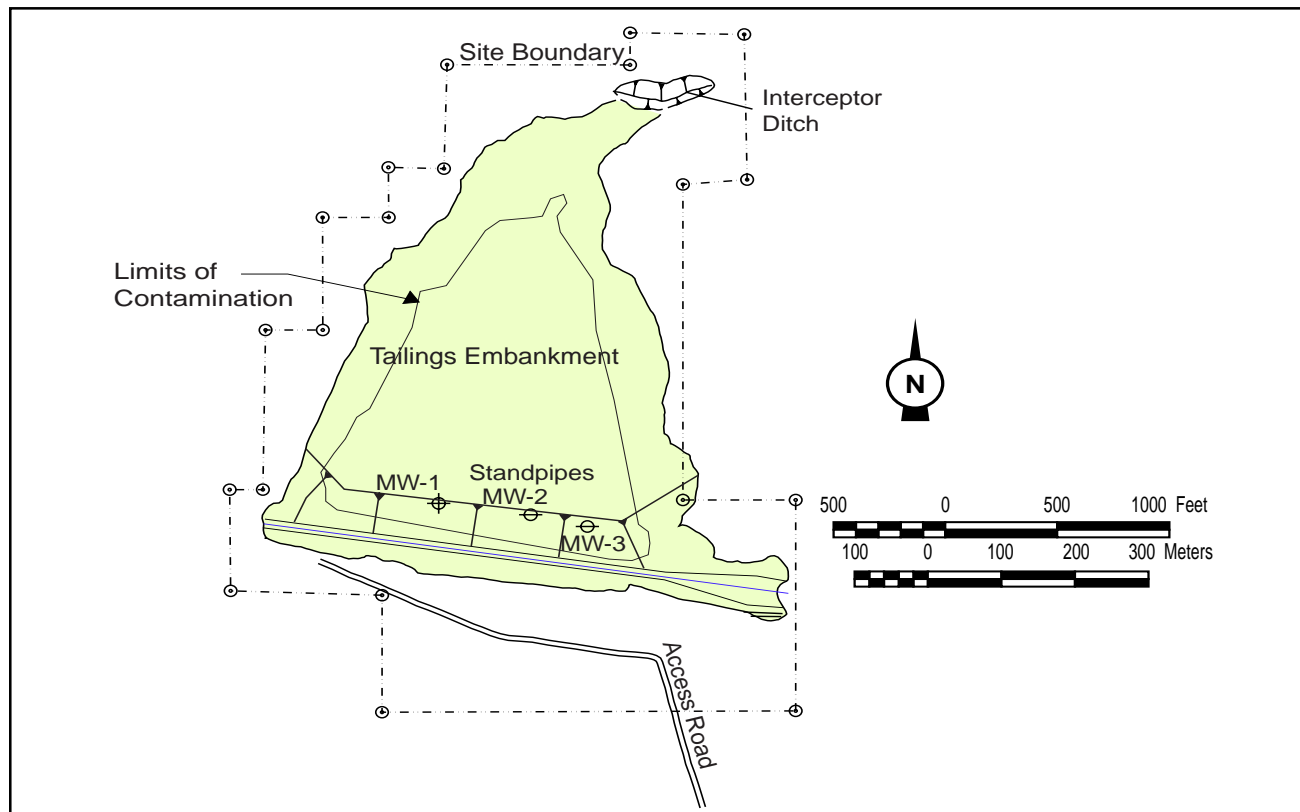
Site Specific Cell Design Features

Cell Stability and Transient Drainage

The site selected for the Rifle disposal cell was the optimal site from a local political point of view, but was not an optimal location from an engineering standpoint. Because of the site's hillside loca-

tion, the cell design had to include special considerations of cell stability and measures to prevent a surface expression of leachate from the toe of the downhill slope. To obtain material for the construction of the cell's frost barrier and radon barrier layers and to expose more permeable unweathered bedrock, the bottom of the cell was excavated below grade into bedrock in the downslope lower half of the cell.

Because of transient drainage water encountered at the toe of the Durango, Colorado, cell, there was concern that the below grade bowl-shaped bottom of the Rifle cell would act as a "bath tub," to collect transient drainage, and result in an overflow at the base of the downhill slope. To address this concern several innovative tests and analyses were performed to check the cell design. The permeability of the steeply dipping bedrock strata was tested *in situ* by use of special SDRIs (sealed double ring infiltrometers) tests. Special laboratory testing and apparatus were used to evaluate the per-



meability of radon barrier clay amended with 4 percent by weight of Wyoming bentonite clay. State-of-the-art unsaturated flow modeling was performed to predict leachate levels in the completed cell. Large diameter (18 inch [46 centimeters]) standpipes were installed and monitored to verify performance of the completed disposal cell.

To prevent lateral seepage from the toe area of the disposal cell during the build up of transient drainage in the cell, a temporary high density polyethylene (HDPE) liner was installed on the excavated slope at the toe of the cell. The amount of water anticipated to collect in the Rifle disposal cell was greater than any of the other UMTRA sites because the Rifle cell has more wet “slime” tailings than any of the other relocated UMTRA cells. Design, analysis, construction and monitoring of the Rifle cell were all impacted by modifications made to prevent water from collecting in and seeping out of this cell. Although geosynthetic liners did not meet the longevity requirements for permanent use in controlling seepage from UMTRA cells they were suitable for use as a temporary liner at the toe of the Rifle cell. Calculations were made to estimate how high water would collect in the cell from transient drainage. Calculations were also made to estimate how long it would take for equilibrium of pore water in this cell to be established, and for transient water to flow into the foundation of the cell. The liner installed at the toe of the disposal cell was designed to act like a dam, and prevent seepage of transient drainage water from the toe of the cell. Computer modeling predicted that the water level in the disposal cell will fall below the bottom level of the liner in approximately 25 years. Accelerated aging test data provided by the liner manufacturer indicates that the material has a projected life of 30 to 50 years.

The deep excavation at the south end of the disposal cell forms a “bowl” shaped structure which is used to collect, contain and control release of leachate from the cell as discussed above. Additional foundation excavation was conducted in the “bowl” area to expose a more permeable sandstone

formation, that will expedite the downward percolation of tailings drainage.

A leachate collection and removal system was constructed at the south end of the disposal cell in the “bowl” area at the tailings/bedrock interface. The collection system consists of a sand drain blanket and collector rock drains. Three 18-inch (46 centimeters) diameter monitoring/pumping wells were installed as part of the leachate collection/removal system. The high density polyethylene (HDPE) seepage cutoff liner installed at the downstream face of the excavation trench contains leachate within the disposal cell foundation so that it can be monitored and pumped out if necessary. These temporary provisions were made to alleviate Nuclear Regulatory Commission concerns about the “bathtub” effect in the disposal cell foundation.

Erosion Control Features

An interceptor ditch was built at the north end of the disposal cell to intercept drainage from the area above the cell and discharge it in a westerly direction, away from the disposal cell. The design approach is that future erosion will progressively incise into the underlying alluvium and Wasatch bedrock formation, until it reaches a stable elevation. The direction of gully incision would be from the west (the outlet) towards the east (upper end) of the ditch. This would not affect the disposal cell, which is south of the ditch. The ditch gradient is relatively steep (greater than 15 percent), which is expected to prevent the ditch from being blocked by sediment or debris which could cause flows to be diverted onto the tailings embankment.

The top of the disposal cell was constructed flush with the adjacent ridges on the east and west to avoid runoff from these features onto the disposal cell top slope, which could create flow concentrations on the riprap.

Salt Lake City, Utah

Site Description

The South Clive disposal site is located approximately 70 miles (113 kilometers) west of Salt Lake City, Utah.

Cell Dimensions

The disposal cell is approximately 54 acres (22 hectares) in size, rectangular in shape, and constructed partially below grade. It rises 35 feet (10 meters) above the surrounding terrain, and is approximately 2,100 feet (640 meters) long and 1,115 feet (340 meters) wide. It is approximately 40 feet (12 meters) deep from its highest to its lowest point.

Site Specific Cell Design Features

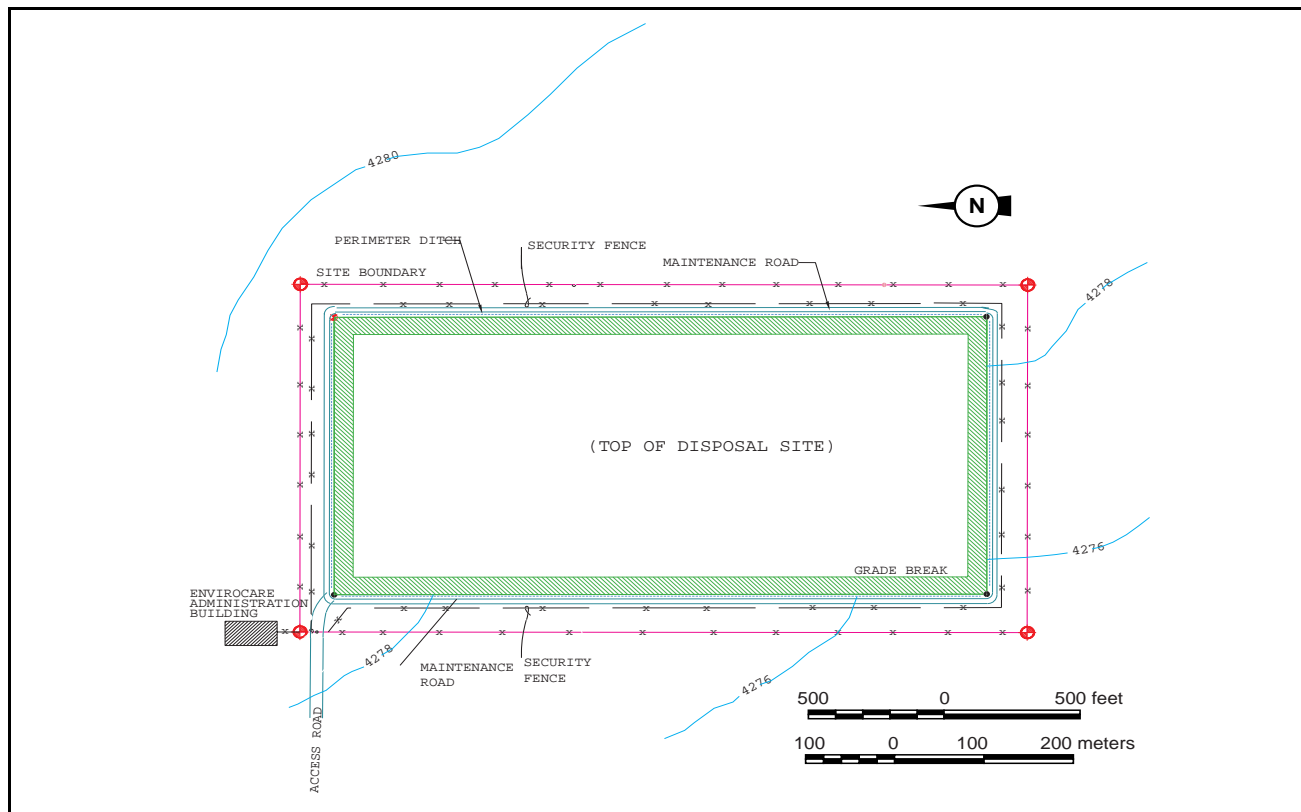
Design and construction of the Clive disposal cell was performed by the State of Utah.

Knowledge of the MK Engineering Assessment of the Clive disposal cell is essential for evaluat-

ing the disposal cell conditions, especially the cover that was reworked in 1996 prior to Nuclear Regulatory Commission approval of the site. (The completion report includes an appendix that describes final remedial work performed prior to licensing.) The Engineering Assessment was based on the as-built conditions, i.e., a performance assessment of the construction, as opposed to the typical UMTRA project approach of design approval and construction compliance. The performance assessment was required because some items did not conform to the approved design and because state documentation for design compliance was lacking for other items.

Some examples of items that were addressed in the Engineering Assessment are as follows:

- A. A key item was the riprap size that was placed. Available documentation indicated that the riprap size did not conform to the original construction specification in the State



of Utah design. Measurements and calculations performed during the UMTRA Remedial Action Contractor's Engineering Assessment showed that the as-placed riprap sizes, although smaller than specified, are adequate.

- B. Irregularities in the as-built riprap surface were assessed, and irregularities that could affect the performance of the disposal cell were repaired. The irregularities that remain were not considered detrimental to the long-term performance of the tailings embankment. The riprap was determined to be stable with the small flow concentrations that could occur in the irregularities that were not repaired.
- C. Soil visible in riprap may be unsightly but the above-cited engineering assessment concluded it is not a cell performance issue. Some soil is mixed with the riprap and is visible from the surface at various small, isolated locations. Sufficient riprap exists at the locations where soil was visible based on several checks that were made by digging into the soil/riprap mixture.
- D. The required average radon barrier thickness is approximately two feet (60 centimeters). An average of approximately seven feet (2 meters) thick was placed and compacted on this cell, according to quantity records. Major biological intrusion would be needed to cause an exceedence of the radon flux limit. Long term surveillance and maintenance activities should include surveillance for and prevention of large-scale biointrusion disturbance of the radon barrier layer on this disposal cell.
- E. Settlement plate data indicated that post-construction settlements were small. The small settlements helped reduce concerns regarding inadequate compaction of some of the tailings materials placed in the cell. Continued monitoring of settlement plates on the cell

is not considered necessary for technical purposes. Excessive settlement or subsidence of either the embankment or the foundation is considered to be improbable.

Degradation of Outer Perimeter Ditches

Degradation of the condition of the outer perimeter ditches at the site is not considered to be a potential problem. The outer perimeter ditches are not essential to the performance of the disposal cell, because they were not designed for long term erosion protection of the tailings embankment.

Ponded Water in Perimeter Ditches

Ponded water in perimeter ditches should not impact long term stability of the disposal cell. Riprap quality is adequate to resist degradation from freeze-thaw in frequently saturated areas.

Proximity of Other Waste Disposal Activities

One nontypical characteristic of the Department of Energy disposal site at South Clive, Utah is the proximity of other waste disposal landfill activities. Design features, other than the typical security fence and the bollards around some survey monuments, were not constructed specifically to reduce the potential for impacts from nearby human activity. Encroachment by construction and waste transfer activities in the surrounding areas is expected to be one of the more likely threats to the condition of the disposal site. The effects of these activities should be monitored by long term surveillance and maintenance personnel. Encroachment on the DOE site property has already occurred.

Gully Erosion

Gully erosion is not expected to affect the disposal cell. Formation of deep gullies that could advance rapidly towards the site by headcutting is considered unlikely due to the small gradient of surrounding land and the relatively high regional base level.

Shiprock, New Mexico

Site Description

The Shiprock disposal site is located on approximately 80 acres (32 hectares) of Navajo Nation land adjacent of the south bank of the San Juan River in the town of Shiprock, New Mexico.

Cell Dimensions

The residual radioactive materials was stabilized in place. The above ground disposal cell covers approximately 77 acres (31 hectares) and is an asymmetrical pentagon. The cell is approximately 2,150 feet (655 meters) long by 1,700 feet (520 meters) wide and rises some 48 feet (15 meters) above the original ground surface.

Site Specific Cell Design Features

Ditches Designed for Half of Probable Maximum Precipitation

The northeast and northwest ditches adjacent to the cell were designed for one-half of the probable

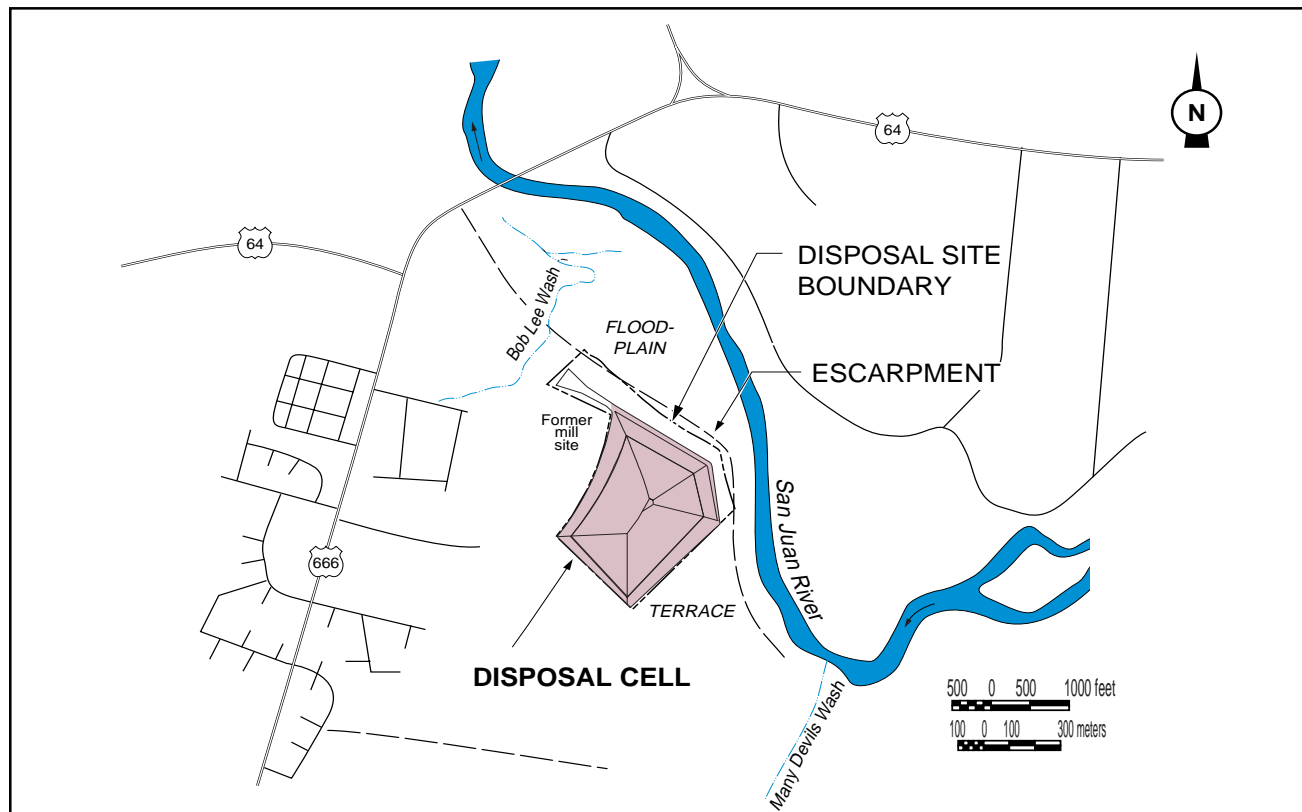
maximum precipitation. The ground surface adjacent to the ditches was considered unlikely to be eroded by infrequent ditch overflow, and the available rock sizes were not large enough for a full probable maximum precipitation design. Therefore, the ditches were designed to spill excess flow over the outside edges before the flow rate exceeds the maximum flow rate for riprap stability.

Ditches Near Cliff above San Juan River

Ditches along the side of the tailings embankment near the cliff above the San Juan River were lined with compacted clay to reduce any seepage that might travel laterally and exit at the face of the cliff.

Radon Barrier Thickness

Sandy silty soils were locally available for use in constructing the cover for the Shiprock disposal cell. On several cells designed later in the UMTRA project, powdered bentonite clay was mixed with



the locally available soil to construct a low permeability radon barrier layer. Without using bentonite additive for this disposal cell cover, a much higher radon diffusion coefficient had to be used in the design. As a result the radon barrier layer used on the Shiprock disposal cell is seven feet (2.1 meters) thick on the side slopes and six feet four inches (1.9 meters) thick on the top slope areas. The amount and placement of less contaminated windblown and other material was not sufficient to reduce the radon flux substantially from the more contaminated tailings. Measurements of radioactivity after contaminated material placement were used to optimize the radon barrier thickness.

Slick Rock, Colorado

Site Description

The Burro Canyon disposal site is located on public land formally administered by the Bureau of Land Management. The disposal site covers approximately 76 acres (31 hectares) and is located approximately three miles (5 kilometers) northeast of Slick Rock, Colorado.

Cell Dimensions

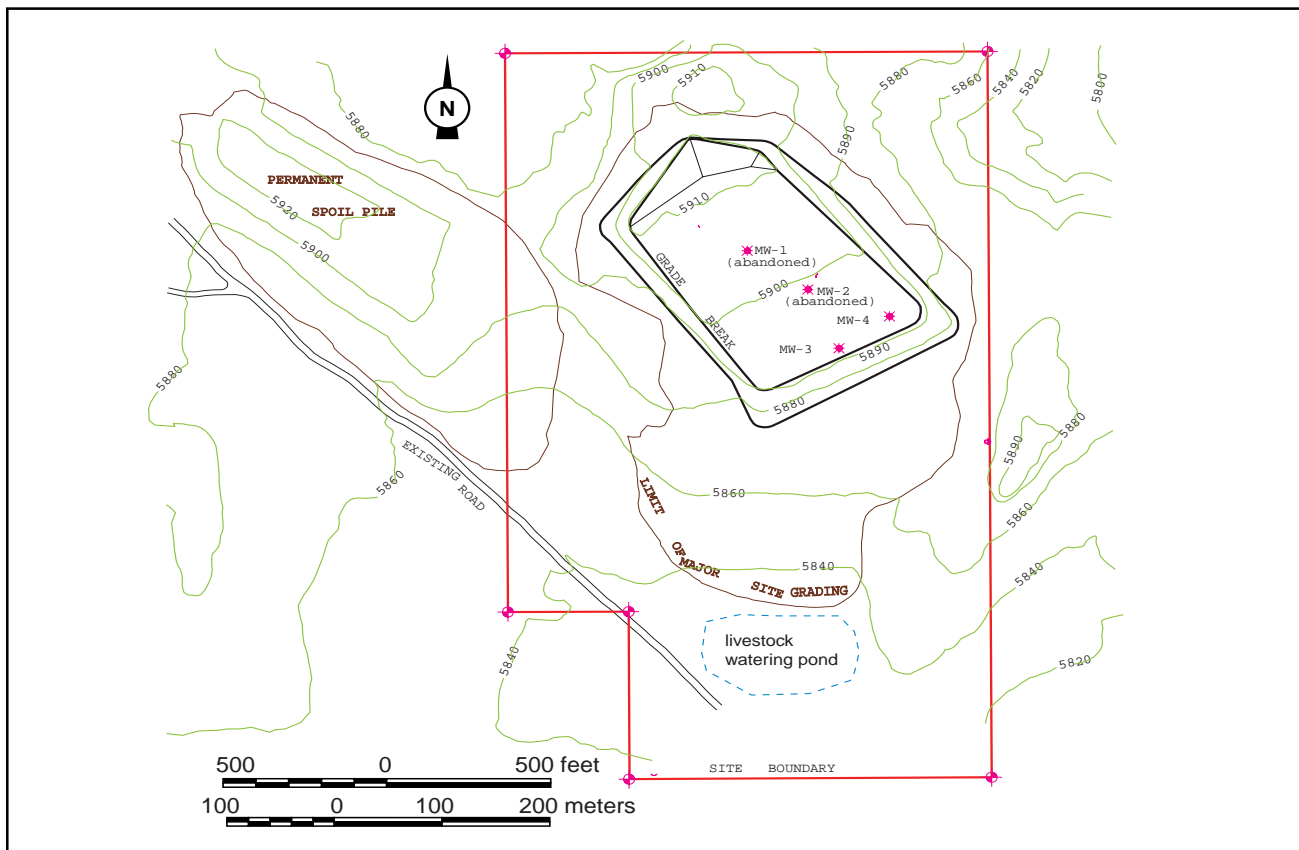
The residual radioactive material was relocated to the Burro Canyon site from two uranium processing sites located near Slick Rock - the Union Carbide site and the North Continent side. The disposal cell covers 12 acres (4.9 hectares) and is roughly rectangular in shape. The cell is approximately 900 feet (275 meters) long by 650 feet (200 meters) wide. It rises some 65 feet (20 meters) above the surrounding terrain and is approximately 95 feet (30 meters) deep from its highest to its lowest point.

Site Specific Cell Design Features

Disposal Cell Placed Below Grade

Most of the disposal cell is below grade. The bottom of the cell slopes toward the southeast. Both the bottom and sides of the cells are unlined. The relatively deep excavation was performed for the following reasons:

1. To obtain radon barrier material.
2. To reduce the overall surface area of the cell, which required less radon barrier and riprap, and allowed smaller riprap rock sizes to be used.
3. To allow some transient seepage to saturate the lower portion of the tailings without allowing the saturated zone to contact one of the more permeable rock strata.



Standpipes

Experience at other UMTRA project sites indicated that pore water could accumulate within the contaminated materials during and shortly after construction. Therefore, four standpipes were originally installed in the placed tailings to check if the prediction of minimal buildup of saturation was accurate. Standpipe data indicated significantly higher water levels than the predicted water levels. However, the standpipes may not have indicated the true piezometric levels in the surrounding tailings due to their construction, which may have allowed surface water to seep and collect in the stand pipes. Measurements eventually showed a slow drop off in the pore water levels, indicating that the pore water was seeping out of the cell faster than seepage was accumulating in the standpipes.

Two of the standpipes have been sealed and abandoned. The two remaining standpipes will be used to monitor the level of transient drainage in the cell.

Key Trench Drainage

The key trench for the apron was constructed around the perimeter of the cell to a low point on the southeast side of the cell. A wide drainage blanket was constructed to prevent significant surface erosion at the location where drainage occasionally exits the key trench. Rills and wet spots beyond the drainage blanket are not considered a threat to the cell stability.

Livestock Watering Pond

The livestock watering pond was planned to be left indefinitely, (i.e., the pond is not considered a temporary feature which is planned to be backfilled).

Spook, Wyoming

Site Description

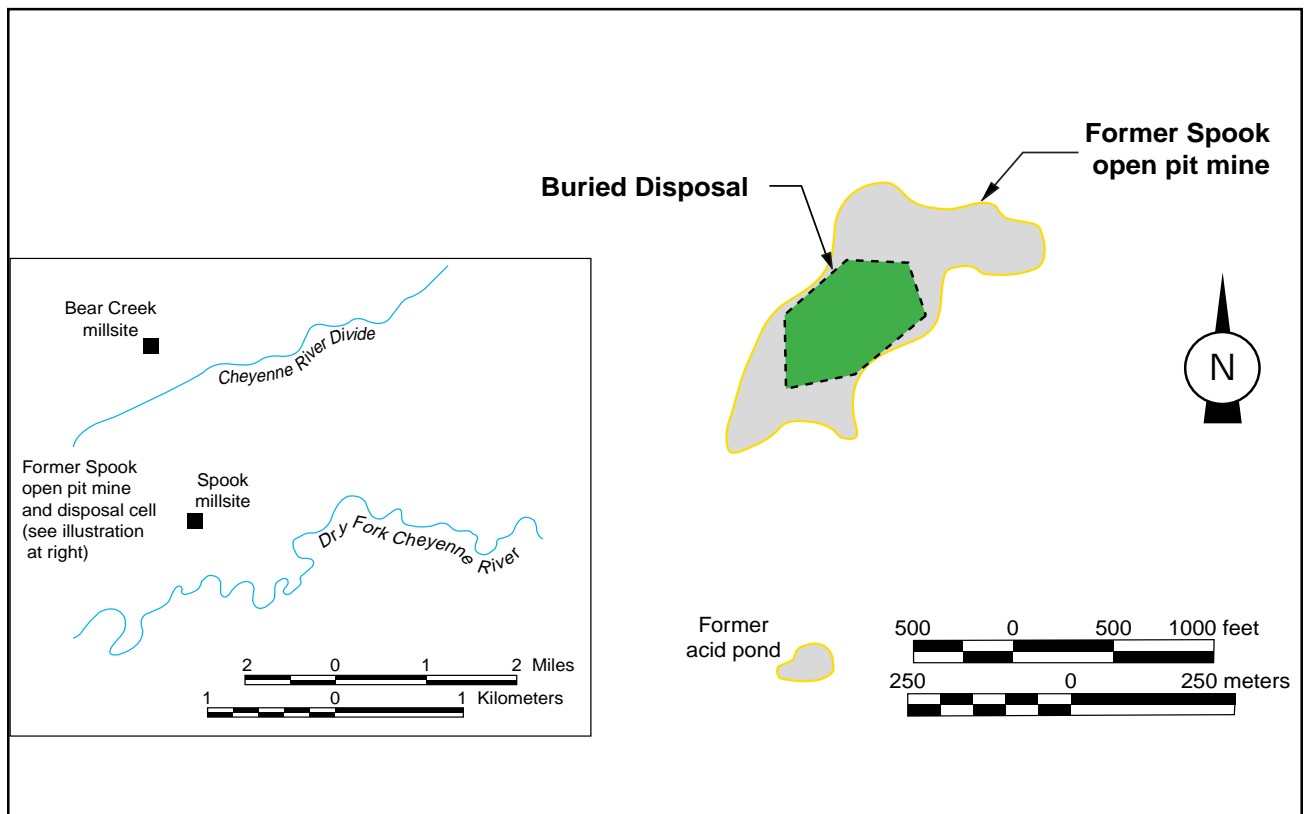
The disposal site is approximately 32 miles (52 kilometers) northeast of Glenrock, Wyoming. The site covers approximately 55 acres (22 hectares).

Cell Dimensions

The Spook disposal site contains residual radioactive material that was stabilized on the former mill site. The disposal cell is roughly oval in shape and is approximately 740 feet (225 meters) long by 550 feet (170 meters) wide. The cell is 54 feet (16 meters) deep from its highest to its lowest point. The disposal cell is not visible at the surface because it was covered by 55 feet (17 meters) of back-fill as part of the State of Wyoming's mine reclamation program.

Site Specific Cell Design Features

There are no unique engineering features associated with the design and construction of the Spook disposal cell. The contaminated materials are buried in an open pit uranium mine. The tailings are covered with a 1.5-foot (46 centimeters) thick, low-permeability layer and then covered by a ten-foot (three meter) thick high permeability layer. The entire cell was then buried with 35 to 55 feet (10 to 17 meters) of soil. The site's surface was contoured to approximate pre-mining topographic conditions and seeded with native grasses.



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Tuba City, Arizona

Site Description

The Tuba City disposal site is located within Navajo Nation land and is approximately 5.5 miles (9 kilometers) east of Tuba City, Arizona. The 50 acre (19 hectares) disposal cell is located on the 145 acre (54 hectares) disposal site.

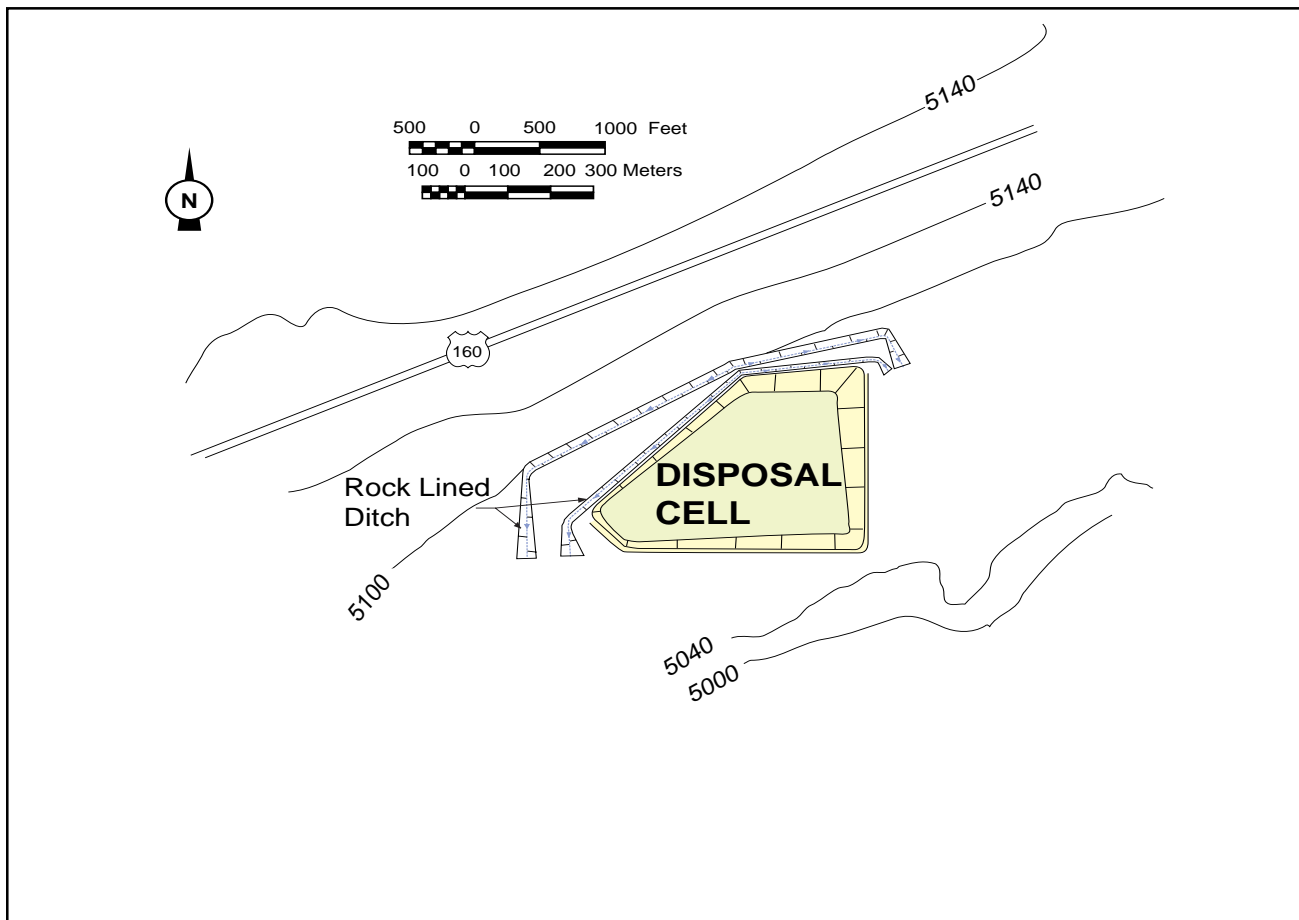
Cell Dimensions

The residual radioactive material was stabilized in place. The above-ground disposal cell was constructed on gently sloping terrain and is roughly triangular in shape. It rises 44 feet (13 meters) above the surrounding terrain and is 2,200 feet (670 meters) long by 1,585 feet (480 meters) wide.

Site Specific Cell Design Features

Ditch Design

A drainage ditch on the north and west sides of the cell directs runoff water away from the site. Sediment is expected to accumulate in the ditches due to material transported into the ditches by either runoff water or wind. Ditches were designed for adequate flow velocities that would flush any sediment accumulations.



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